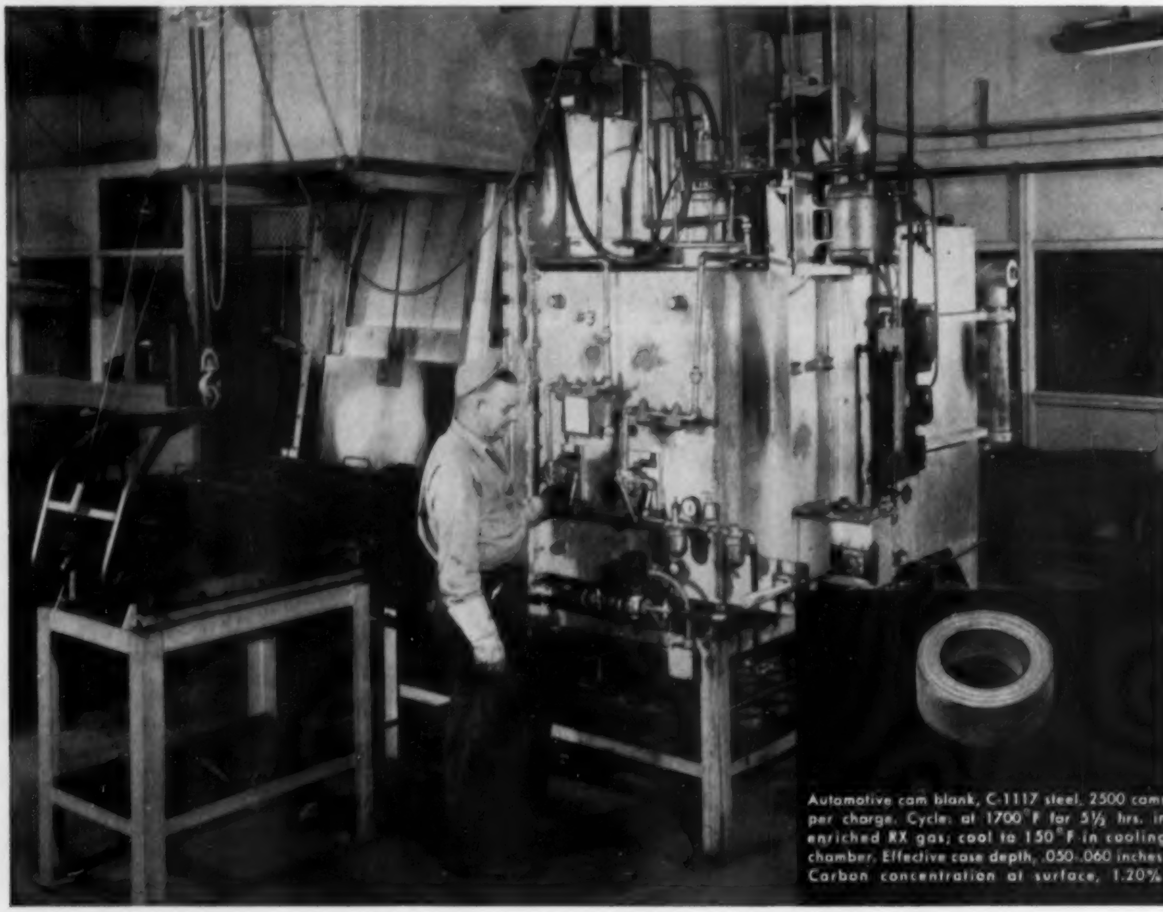
# METAL
# *PROGRESS*

APRIL 1955



Automotive cam blank, C-1117 steel. 2500 cams per charge. Cycle: at 1700°F for 5½ hrs. in enriched RX gas; cool to 150°F in cooling chamber. Effective case depth, .050-.060 inches. Carbon concentration at surface, 1.20%.

# ALLCASE FURNACES PAY OFF FOR AUTO-LITE

Ability to handle increased production schedules has benefited The Electric Auto-Lite Company, Toledo, Ohio, since they installed 'Surface' ALLCASE furnaces for gas carburizing automotive parts.

Results achieved on cam blanks typify the advantages of these furnaces. By utilizing ALLCASE furnaces and an RX® gas generator, closer control of the surface carbon has been achieved and, as a result, physical characteristics of the parts are considerably improved. Rejects have been cut drastically. By changing from pack to gas carburizing, savings have also been realized from reduced handling and the elimination of pack material, pots, fireclay, and necessary cleanup.

Wherever you want high volume batch production for any controlled atmosphere process, specify the cost-cutting ALLCASE furnace. It's equipped with radiant tubes; cooling chamber or enclosed quench, or both; and can be fully automatic from charge to discharge.

● Call your 'Surface' engineer or write for Bulletin H54-10.

**Surface**
HEAT TREATING EQUIPMENT

**SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO**

# Metal Progress

Volume 67, No. 4

April . . 1955



Cover Design by MELVIN BUTOR

**Engineering Articles**



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## Contents Continued

# As I was saying...

THIS HAS sure been a busy month, hardly had time to breathe or pant! However, the crest of the high road was reached about the middle of March – and you know that when you can see the top you heave a sigh of intense relief, take a deep breath of highly rarified air, and attack the wild cats in their den.

This flood stream of activities reached its crest just about press time of this issue of *Metal Progress*, when the multitudinous details of the Ninth Western Metal Congress and Exposition were completed and set in type for the official program. It has been an inspiring activity and culminated in the largest and the most successful of all our previous western events.

It's difficult for many to realize that metropolitan Los Angeles and Southern California house 60% of the total manufacturing industry of the entire state. And I am told the City of Angels is the third largest city in the U.S.A. In the early days of the A.S.M.'s Congress and Expositions, it was always the plea to bring out eastern speakers to run an educational-lecture type of program – but now the ABC's no longer appeal, and you must present the very latest developments and research if you are to have a technical appeal. Consequently the program for this year's Congress was made up by contributions of the leading metal scientists of both the East and the West.

The western divisions of 24 national technical societies cooperated with the A.S.M. in sponsoring these western events, and would you believe it, the total membership of the 24 sections is 20,842. . . .

If you do not think there is a shortage of engineers, you should see a copy of the Sunday Los Angeles *Times*. In the want ad section you will find more than five pages of ads for engineers. There seems to be more research in metal lines in Southern California than in any other similar-sized territory in the States. The shortage is really here – there is no disputing that fact – and what's more, there seems to be nothing we can do about it now or for the next five or six years.

The A.S.M., as you know, has gained wide recognition for its constructive efforts and contributions to secure increased enrollment in engineering schools – even going into the junior and senior high schools to create an interest in science.

The chapters are doing fine work at career conferences, via TV and radio programs, scholarships, and interesting high-school science teachers in the metals industry.

These concentrated efforts are sure to bring results – not overnight, of course, but by constant effort applied at the right spots the needed engineers will become available and do their part in making and shaping the "U.S.A. of Tomorrow".

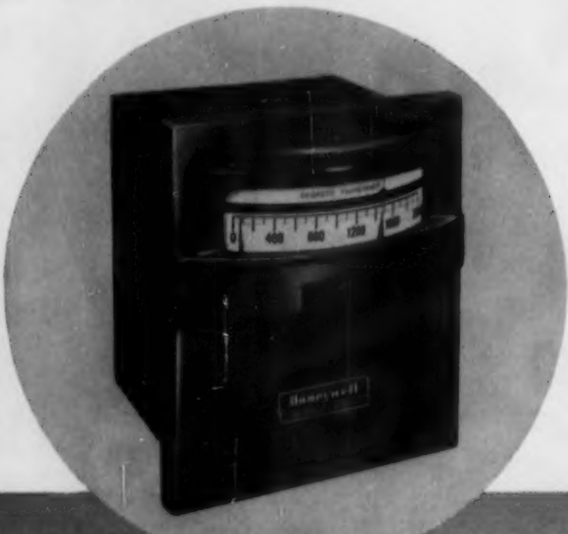
Cordially yours,

*Bill*

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

Actual Size 11" x 12"


# *For reliable, economical*

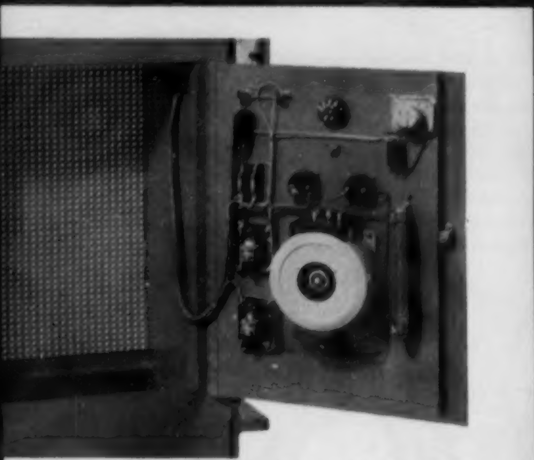


### Pyr-O-Vane Controllers

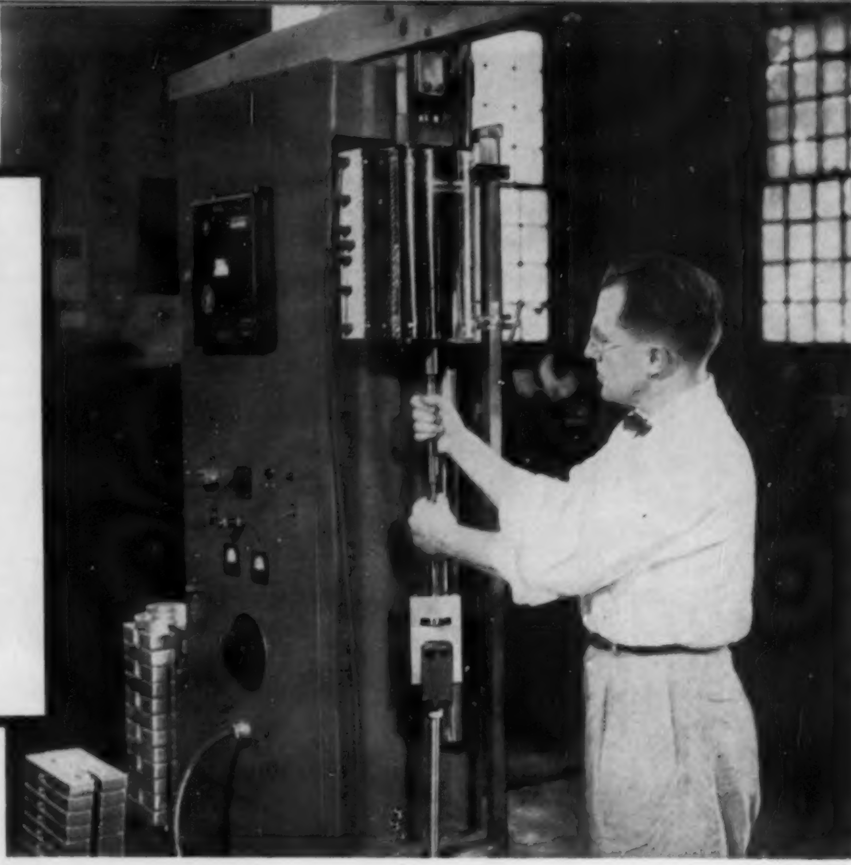
*Horizontal-case* model fits standard 19" relay racks. Available in a choice of control actions, including three-zone control with neutral zone adjustable from 0 to 100%, or 0 to 10%. Pre-wired panel permits checking of thermocouple or millivoltmeter without disconnecting wiring.

*Vertical-case* model can be flush or surface mounted.

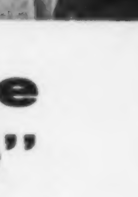
Both types are available with "snap action" electronic vane control; on-off, two-position and three-position; and with pulse-type time-proportioning control. They are designed for fail-safe operation, and are virtually unaffected by changes in line voltage, humidity and temperature. Supplied with either thermocouple or *Radiamatic*® calibrations.



Complete electrical equipment is mounted integrally on the machine.







# engineering digest OF NEW PRODUCTS

### *High Temperature Tests*

Trop-Arctic Temperature Products has announced a unit for high temperature testing applications. It is of 1 cu. ft. capacity with a temperature differential of 1° F. throughout a range from ambient to 400° F. A six position switch gives a selection of

five heats ranging from 90 watts to 1500 watts. Thermal breaker strips and insulation assure minimum heat loss and safe outside temperatures. Liquid bath chambers are available throughout a temperature range of —120 to 400° F. and may be designed for varying rates of temperature changes.

**For further information circle No. 898 on literature request card, p. 36-B.**

### *Alloy Steel*

A new type of alloy steel, with unusually high resistance to impact and abrasion, has been announced by American Steel Foundries. Its high initial hardness (470 to 520 Brinell) is combined with high resistance to impact. This initial hardness is retained in sections up to 6 in. thick, with only a slight reduction in hardness of thicker sections. Wearpact has a tensile strength exceeding 220,000 psi. in the normal range of 470 to 520 Brinell hardness. Yield point exceeds 180,000 psi. These values are retained at operating temperatures ranging from 450° to —50° F. Charpy impact values are approximately 30 ft.-lb. It has been cast in the form of large crusher segments, down to the smaller sized dipper teeth. Shrinkage rate is comparable to that of most cast steels and special patterns are not usually required.

**For further information circle No. 899 on literature request card, p. 36-B.**

### *Burners*

Hauck Mfg. Co. has announced a new combination burner for radiant tube firing in controlled atmosphere furnaces. The flame length can be changed to fit the tube, by means of the flame adjusting lever. More uniform heat distribution within a radiant tube is thus obtained. Either oil or gas can be burned.

**For further information circle No. 900 on literature request card, p. 36-B.**

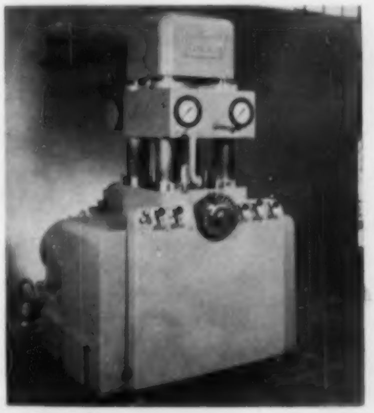
### *Rust Remover*

Enthone, Inc., has announced a new nonelectrolytic alkaline derusting compound. It is a free-flowing powder that is used in a concentration from 1 to 3 lb. per gal. of water. There is no attack upon the base steel which is left clean and bright and because of its high alkalinity, paints, organic coatings and other surface contaminants are removed together with rust.

**For further information circle No. 901 on literature request card, p. 36-B.**

### *Hydroform Machine*

The new 8 in. hydroform machine has been announced by the Process Machinery Div. of Cincinnati Milling Machine Co. Hydroforming embodies



the use of a male punch, and a flexible die member backed up by hydraulic oil pressure which may be accurately controlled up to 15,000 psi. The new machine will form parts from sheet metal blanks up to 8 in. in diameter with a maximum draw depth of 5 in. Practically all sheet metals in gages up to ¼ in. steel can be drawn. The maximum machine operating rate is 200 cycles per hour. The machine is self-contained, floor mounted, 5 x 5 x 7½ ft., weighs 12,000 lb. and requires only water and electrical connections to be put into operation.

**For further information circle No. 902 on literature request card, p. 36-B.**

### *Wire Machine*

New wire straightening and cutting machines have been announced by the Lewis Machine Co. Two models are available, No. 2-C3 for wire from 1/16 to 3/16 in. and No. 2-C4 for wire from 3/32 to ¼ in. The 2-C wire straightening and cutting machines

feature straightener arbor support brackets for minimum vibration; completely enclosed straightener arbor guard to keep oil off machine and V-belts; heavy section V-belts with large pulleys; modern flush mounted electric control buttons; higher speed, five die straightener arbor, mounted on ball bearings. Solenoid-operated trip mechanism is available and is recommended for small diameter wire sizes.

**For further information circle No. 903 on literature request card, p. 36-B.**

### *Brazing Flux*

A special flux for silver alloy brazing of stainless, chromium heat resisting alloys, chromium and tungsten carbides has been announced by Handy & Harman. The new flux will reduce oxides of the refractory metals while protecting the underlying metal from further oxidation during brazing. It will withstand heating at 1400 to 1600° F. for short times. The flux contains a strong deoxidizer and one whose oxide is a flux former. In a sense the flux re-

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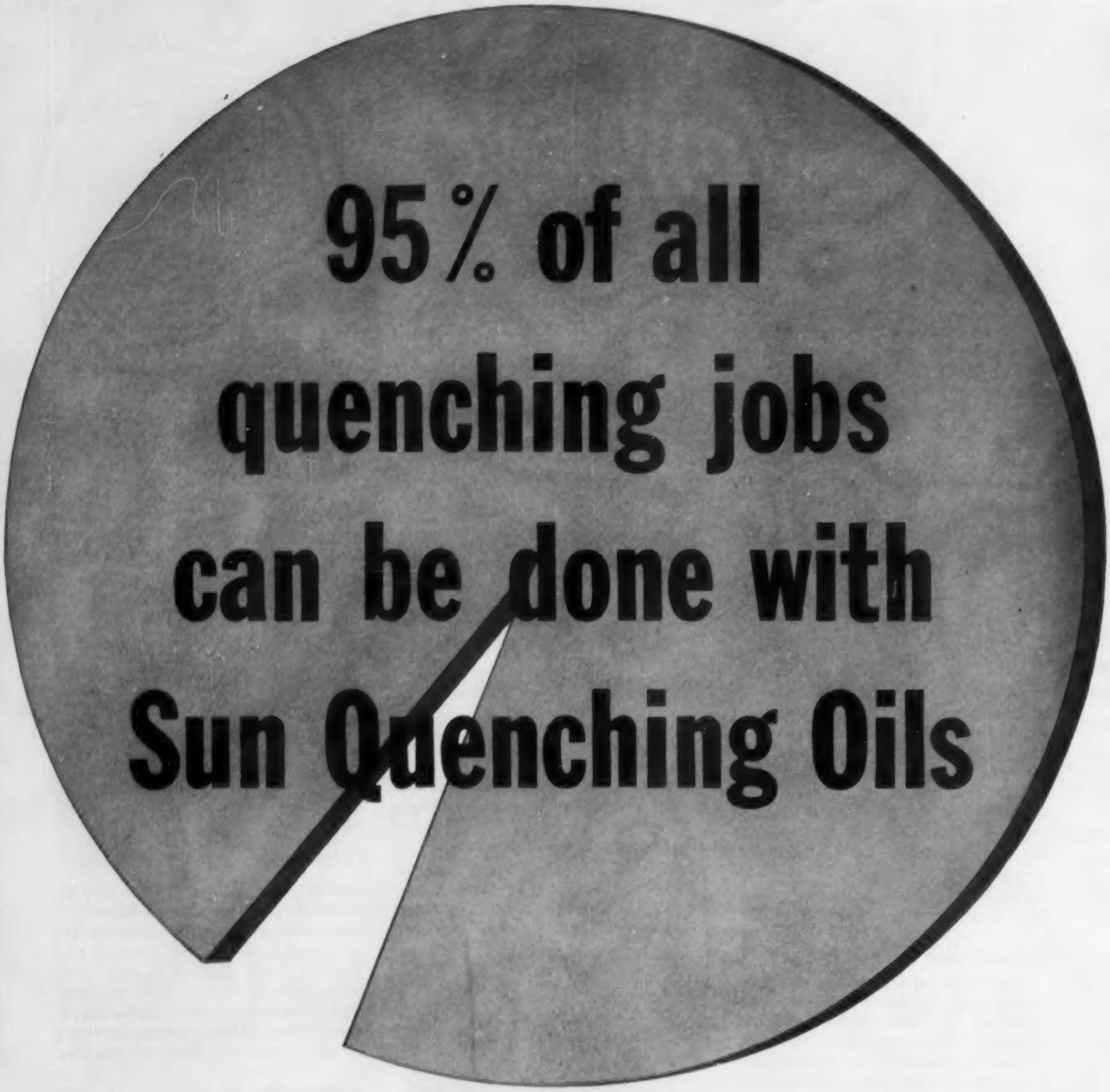
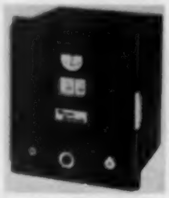


generates itself during the heating cycle and thus provides the longer activity span required for elevated temperatures. After brazing, the flux can be removed with hot water.

**For further information circle No. 904 on literature request card, p. 36-B.**

### *Indicator*

Thermo Electric has announced a manual-balance indicator for null balance measurements for applications where the speed of the self-balancing indicator is not required. It is used for direct reading of temperature differences by the use of two resistance bulbs connected opposed to each other, to the same indicator. Temperature differences as small as 0.02° F. can be measured.



**For further information circle No. 905 on literature request card, p. 36-B.**

### *Inspection*

General Scientific Equipment Co. has announced the new Syte-Ayde which provides light for inspection in out-of-the-way places. Powered by flashlight batteries, the Syte-Ayde provides four light transmitting rods. Two are straight, 3½ and 6 in. long, and two of the same lengths are bent 90 deg. Three 1½ power mirrors, ½, ¾ and 1¼ in. in diameter are supplied with clips which fit rod ends. All parts are contained in separate compartments of a plastic kit.

**For further information circle No. 906 on literature request card, p. 36-B.**

### *Polishing Tables*

Buehler, Ltd., has announced a new streamlined all-metal polishing desk in single, two or three unit models. The polishing table is desk-high and finished in grey hammertone. The top is of black Formica. Wash bowls are of vitreous enameled iron, and 12 in. swing spouts supply water either to the polishing wheel or the wash bowl. The polishing heads are direct-drive models 1500-F and 1505-2F.

**For further information circle No. 907 on literature request card, p. 36-B.**

### *Surface Conditioning*

Vacuum Specialties, Inc., has announced a unit for surface conditioning ingot surfaces. An electric arc plays on the rotating ingot so that the entire surface is progressively melted in a helical path. The operation is carried out in a water-cooled furnace chamber under inert atmosphere or vacuum, and is entirely automatic. Highly reactive metals can be processed, since the equipment is built to high vacuum standards of very low in leakage of air. Equipment is custom designed and built for specific user requirements. Ingot sizes up to 16 in. in diameter by 48 in. long are within the capabilities of present design.

**For further information circle No. 908 on literature request card, p. 36-B.**

### *Infra-Ray Gage*

A new gage for measuring red hot steel strip accurately as it travels at rates up to 2000 ft. per min. has been announced by Industrial Gauges Corp. This gage head may be located from

10 to 20 ft. above the hot metal and yet measure widths from 3 in. to 10 ft. Strip temperatures from 900 to 2000° F. do not affect accuracy. Gaging is continuous.

**For further information circle No. 909 on literature request card, p. 36-B.**

### *Heat Treating Furnace*

A 25 lb. per hr. controlled atmosphere heat treating unit for laboratory and research work has been announced by Ipsen Industries. The new unit is built for temperatures up to 2000° F., is equipped with an 8 x 14 x 8 in. hearth, electric radiant-type heating tubes and a sealed quench or cooling chamber. It is capable of hardening, carburizing, carbonitriding and brazing operations. The quench tank and cooling chamber is connected to the forward or loading end of the hearth. The quench tank has a two-speed flow motor and built-in automatic heating and cooling coils.

**For further information circle No. 910 on literature request card, p. 36-B.**

### *Test Chamber*

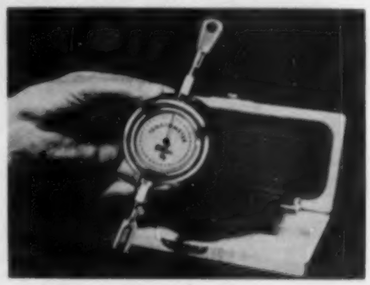
Testing temperatures ranging from —100 to +400° F. made possible by a new portable controlled-temperature cabinet has been announced by Baldwin-Lima-Hamilton. Both tension tests and compression tests are performed in this cabinet, and stress-

strain curves are produced automatically by the recorder. Two heat-insulated hand holes and a window in the door of the cabinet permit manipulation of grips, extensometer, thermocouple, or other accessories inside while tests are in progress at elevated or sub-zero temperatures.

**For further information circle No. 911 on literature request card, p. 36-B.**

### *Proving Ring*

Dillon Co. has announced a 0 to 300 lb. capacity turnbuckle-type proving ring. This new instrument, in addition to reading tensile or compression loads, can be employed to apply a tensile load by simply taking up on the turnbuckle forks at opposite sides.



The new proving ring is furnished with a dial graduated in angular degrees. Translation of readings into pounds is on a separate calibration reference chart. This method also permits a fine increment breakdown.

**For further information circle No. 912 on literature request card, p. 36-B.**

### *Sheet Cleaning Machine*

Pangborn Corp. has announced the development of a new Rotoblast machine which cleans both sides of steel sheet and plate simultaneously, in

**WELDMENTS** of "T-1" Steel—made with AWS 12015 low hydrogen coated electrodes and without pre- or post-heating — develop the full 90,000 psi yield strength. As a result, lightweight designs are completely safe and reliable.

# NEW USS "T-1" STEEL has great potential for reducing cost of pressure vessels

You've heard of Operation "T-1." You've heard how those dramatic tests proved that, when and if higher design stresses are permitted, USS "T-1" constructional alloy plate steel will make possible larger, stronger pressure vessels, vessels that can be built more easily and at lower over-all cost. As a result of Operation "T-1," several major pressure vessel fabricators have requested approval from the ASME to use USS "T-1" Steel in unfired pressure vessels. Why? For mighty good reasons:

"T-1" Steel has a very high yield strength – 90,000 psi minimum – three times that of conventional plate steels now used in pressure vessels. Yet it is extremely *tough* and can withstand high stresses and pressures even at temperatures far below zero. What's more, USS "T-1" Steel remains strong at *high* temperatures up as high as 900 degrees F.

Yet, "T-1" Steel is easy to fabricate. It can be drilled, machined, or cold formed, and welded or flame-cut *without* pre- or post-heating. **"T-1" can make pressure vessels . . .**

**LARGER.** For a given pressure and shell thickness, the *radius* of a vessel may be increased in direct proportion to the ratio of working stresses. Result: more storage capacity at lower cost.

**STRONGER.** For a given radius and shell thickness, the *pressure* may be increased in proportion to the ratio of working stresses. Result: vessels for higher pressures at lower cost.

**LIGHTER, EASIER TO BUILD.** For a given pressure and radius, the shell thicknesses may be reduced, thus permitting larger vessels to be fabricated *without stress relief*. Result: lower fabrication cost.

United States Steel, Room 4669
525 William Penn Place, Pittsburgh 30, Pa.

☐ Please send me your booklet "United States Steel presents T-1" which contains the full story of "T-1" steel.

☐ Have your representative get in touch with me.

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## USS "T-1" CONSTRUCTIONAL ALLOY STEEL

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USS

UNITED STATES STEEL

# "It's the biggest alloy forging

says
Edward Schuerman,
U. S. Steel Hooker Leader

THAT PIECE OF STEEL held by the crane weighs 280,000 pounds. It is 30 inches thick, over 11 feet wide, and 22 feet long. An identical piece lies on the floor. Both will be parts for an extremely large press.

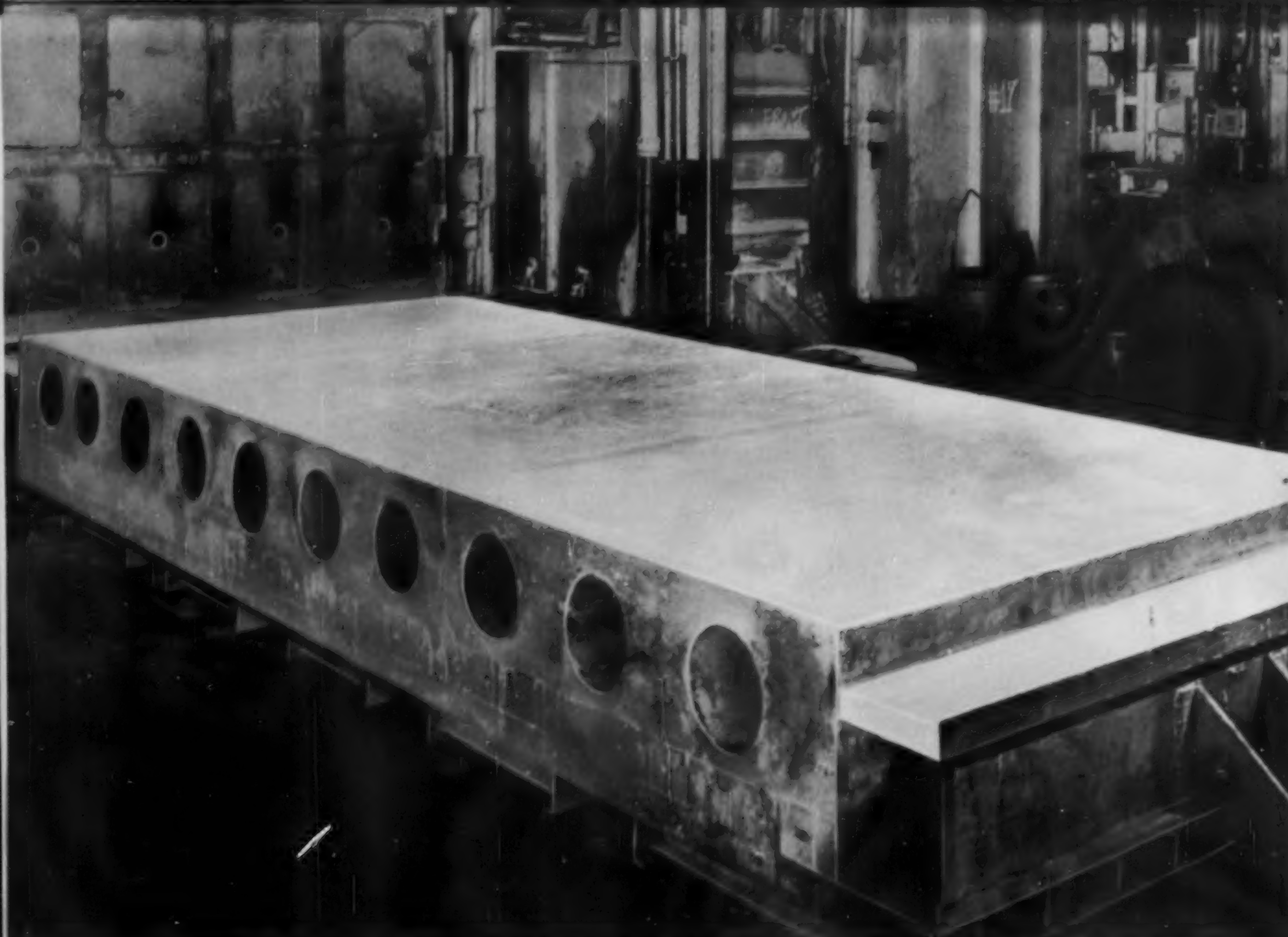
If you are a steel man, you may not be especially impressed by these figures, until you realize that the forgings are made from heat treated alloy steel . . . and the steel for each piece was poured as one heat from a single furnace.

Just *handling* forgings like these is a tough job, a job that falls into the lap of men like Edward Schuerman, Hooker Leader, a U.S. Steel employee for 29 years. He has to choose the correct hook or sling assembly, spot the crane, and supervise the lift. One mistake could delay a shipment by months, but Ed has never dropped a forging in his life.

This is the kind of man who works on every USS Quality Forging. You can put your faith in these men, in the steel that comes from our furnaces, and in the modern equipment that means prompt delivery and highest possible quality.

Write for our free 32-page booklet that describes USS Quality Forgings. Address inquiries or booklet requests to United States Steel, Room 4669, 525 William Penn Place, Pittsburgh 30, Pa.

**SEE THE UNITED STATES STEEL HOUR.** It's a full-hour TV program presented every other week by United States Steel. Consult your local newspaper for time and station.



**REFRACTORY CONCRETE CAR TOP** in use at Commercial Steel Treating Co., Detroit, Mich. This car top is made with Zero ZR-13, a Lumnite-base castable produced and marketed by Standard Fuel Engineering Co., Detroit, Mich. For over 15 years this company has used refractory concrete for car tops and furnace door linings.

# Why does refractory concrete make the best furnace car top?

EASY TO CAST—TROUBLE-FREE SERVICE! Despite repeated thermal shock and temperatures to 1850° F., Refractory Concrete car tops on this particular job gave more than twice the service life of car tops made with previously used materials.

These durable car tops need less maintenance . . . cut over-all costs. Smooth, one-piece sections form an even, level base for castings. And they are easy to make with Lumnite* calcium-aluminate cement and refractory aggregates.

For added convenience, you can use a Lumnite-base castable mix—Lumnite cement plus aggregates selected for specific temperature and insulation needs. All *you* do is add water, mix and place. Castables are made and distributed by leading refractory manufacturers.

You'll find Refractory Concrete made with Lumnite cement excellent for use wherever heat, corrosion or abrasion are problems. Easy to place—by plastering, pouring or cement gun—and it's ready for use within 24 hours! For more information, write Lumnite Division, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), 100 Park Avenue, New York 17, N. Y.

**OFFICES:** *Albany, Birmingham, Boston, Chicago, Dayton, Kansas City, Minneapolis, New York, Philadelphia, Pittsburgh, St. Louis, Waco.*

**"LUMNITE" is the registered trade-mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.*

MM-L-100

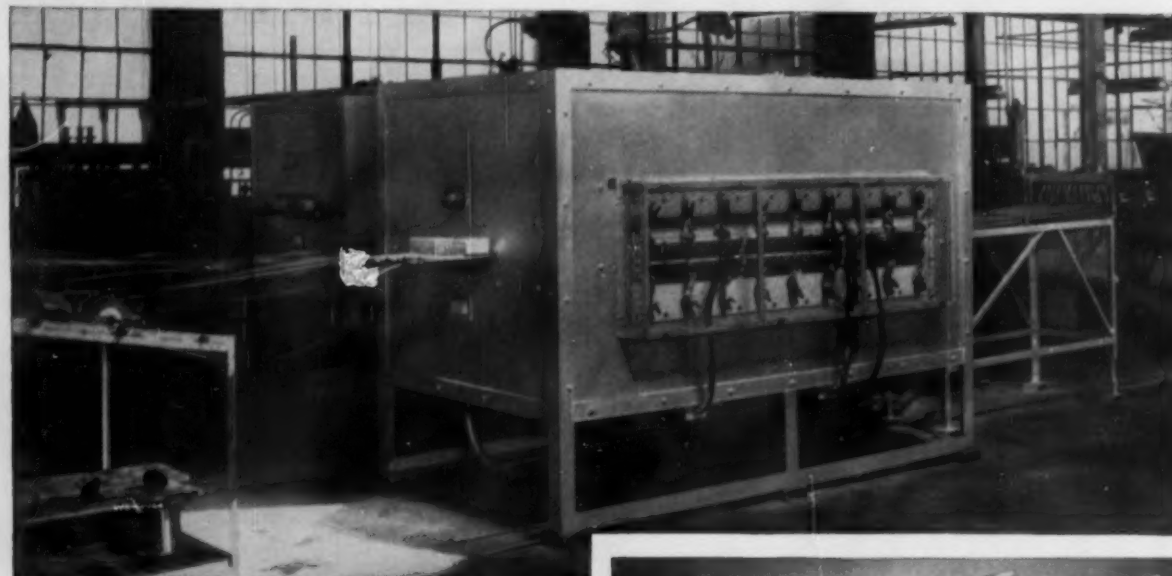
**ATLAS®** **LUMNITE for INDUSTRIAL CONCRETES**

**REFRACTORY, INSULATING, OVERNIGHT, CORROSION-RESISTANT**

A UNIVERSAL ATLAS PRODUCT

UNITED STATES STEEL HOUR—Televised alternate weeks—See your newspaper for time and station

# *More proof that*
# "HOT RODS" last 3 times longer



***Completely Equipped With "Hot Rods"*** after Norton CRYSTOLON heating elements proved their ability to outlast others 3 to 1. This electric furnace is one of a battery operated by the Alloy Metal Wire Division of H. K. Porter Company, Inc. of Prospect Park, Pa., for bright annealing alloy wire at 2150F. Heating elements operate in an air atmosphere, while the wire passes through tubes containing a controlled split-ammonia atmosphere. These furnaces idle at 1700F-1750F on weekends and holidays, so element service is continuous.

***Norton CRYSTOLON Heating Elements,*** or "Hot Rods", are a typical Norton ℞ — an expertly engineered refractory prescription for greater efficiency and economy in electric kiln and furnace operation. Made of self-bonded silicon carbide, each rod has a central hot zone and cold ends. Aluminum-sprayed tips and metal-impregnated ends minimize resistance and power loss. Available in standard sizes.

## *Alloy Metal Wire Division H. K. Porter Company, Inc. converts to CRYSTOLON* heating elements after tests prove superiority of latest Norton ℞*

Like many another new user of "Hot Rods" the Alloy Metal Wire Division of H. K. Porter Company, Inc. found that these Norton CRYSTOLON heating elements last much longer. Here is a summary of the tests responsible for this company's decision to make a complete change-over to "Hot Rods."

***Electric furnaces at the company's Prospect Park plant are used for bright annealing alloy wire at 2150F. Previous heating elements had given approximately 4 to 6 months service with 3,048 hours as the best recorded service life. Then, in a furnace completely equipped with "Hot Rods" the Norton elements averaged 18 months of continuous service — or over 13,000 hours per element. Once again "Hot Rods" proved their ability to outlast competitive elements — by better than 3 to 1!***

But that's not the whole economy-story. The much longer life of "Hot Rods" also means savings in element costs, because fewer "Hot Rods" are needed — *plus* reduced maintenance, due to less frequent changing — *plus* fewer changes in voltage taps — *plus* a smoother production flow.

### *Put these advantages to work for YOU*

in your own electric furnaces or kilns. The big illustrated booklet, *Norton Heating Elements,* gives complete details on how this proved Norton ℞ cuts operating and maintenance costs. For your copy, write to NORTON COMPANY, 323 New Bond Street, Worcester 6, Mass.

NORTON

REFRACTORIES

*Engineered... ℞... Prescribed*

*Making better products... to make your products better*

*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries

widths up to 60 in., at a cleaning rate of 60 to 100 sq. ft. per side per minute. The machine is equipped with four standard Rotoblast wheels which are capable of throwing 112,000 to 132,000 lb. of abrasive per hour. It takes steel sheet or plate into the blast chamber automatically, blasts the top and bottom surface simultaneously at a single point, removes all abrasive from the sheet, and discharges it from the machine. The abrasive is blown off the sheet as it moves past a fan funnel after blasting.
**For further information circle No. 913 on literature request card, p. 36-B.**

### *Ultrasonic Generator*

A new heavy-duty 2 k.w. ultrasonic power generator has been announced by the Branson Ultrasonic Co. The 2000 watt output of the Sonogen generator is fed into a barium titanate transducer at 100,000 cycles per sec.

The transducer, immersed in the cleaning solvent, converts the radio frequency of 100,000 cycles per second into mechanical vibrations which set up a violent agitation in the solvent, shaking dirt and grease loose. A Sonogen 2000 watt generator can drive a transducer with a surface area of 70 to 100 sq. in. or several smaller transducers with the same total area.
**For further information circle No. 914 on literature request card, p. 36-B.**

### *Stainless Steel*

Stainless tubing and pipe of a special intermediate alloy have been announced by the Alloy Tube Div. of Carpenter Steel Co. for applications requiring strong resistance to stress corrosion cracking as well as general corrosion. The steel is recommended for tubing and pipe applications subjected to chlorides, halogen ions, certain caustic solutions and acid conditions associated with food processing. Other successful applications include equipment for chemical processing, pulp manufacturing, petroleum refining and heat exchangers handling brackish water. Carpenter 7 Mo cannot be classified strictly as martensitic, ferritic or austenitic. Nominal analysis is 0.08% max. C, 3.75 to 4.50% Ni, 26.5 to 28% Cr, 1.35 to 1.65% Mo.
**For further information circle No. 915 on literature request card, p. 36-B.**

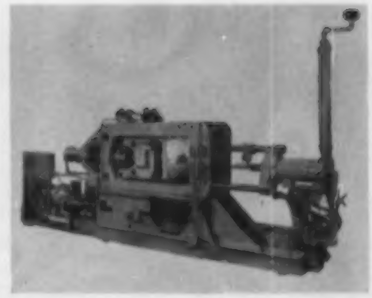
### *Controller*

An indicating controller in the low price range for use on simple industrial processes has been designed by the Foxboro Co. When equipped for on-off action, the new controller snaps the control valve from fully open to fully closed when the measurement crosses the control point, handling any process with large capacity - demand

ratio and negligible lag. For a process requiring throttling action, it is equipped with a proportional unit adjustable from 0.25% up to 25% of scale. It has application in the control of metal plating and cleaning bath temperatures.
**For further information circle No. 916 on literature request card, p. 36-B.**

### *Die Casting Machines*

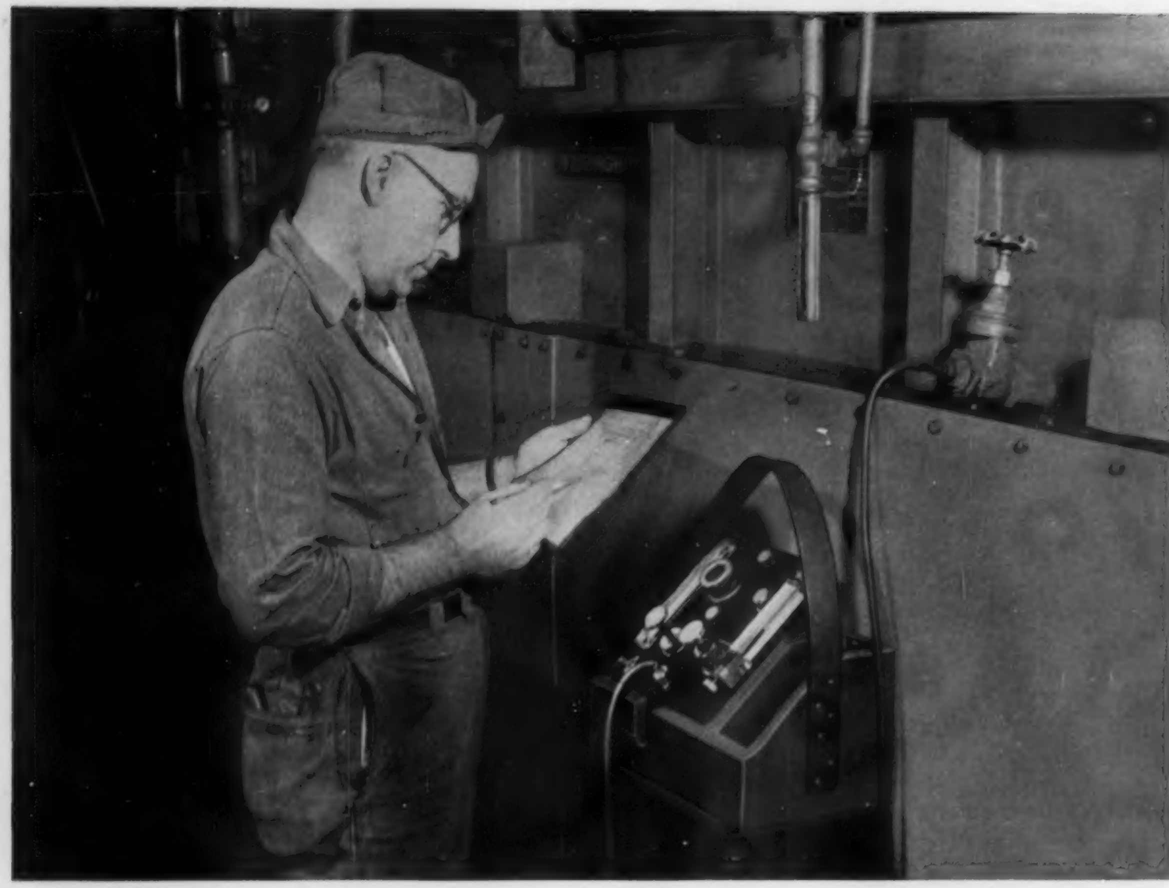
A 600-ton aluminum die casting machine has been announced by Lester-Phoenix, Inc. The machine will



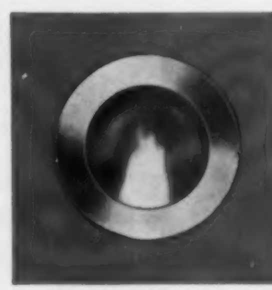
cast up to 16-lb. of aluminum or proportionate weights of magnesium or brass, and is convertible to zinc die casting. It provides 33,200 psi. maximum pressure on metal. Both shot speed and pressure are adjustable, with an ASME approved nitrogen accumulator giving high speed injection. A feature of the machine is the angled support bars of the injection system, which simplifies metal pouring. The water-cooled plunger tip prevents binding.
**For further information circle No. 917 on literature request card, p. 36-B.**

### *Iridium Heating Elements*

Iridium, used as the heating element in a laboratory furnace for calibrating thermocouples for measurement of temperatures in jet engine combustion chambers, has been an-





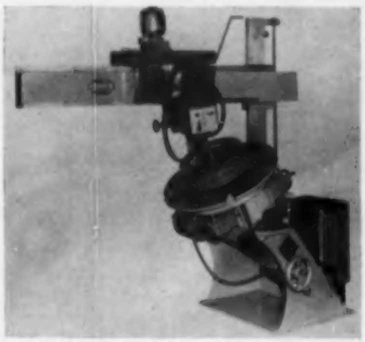


nounced by General Electric Co. Only 500 watts is needed to produce the equivalent of jet engine temperatures from a 6-in. iridium coil. Chief advantages of using the iridium element are ease of control and use of an air atmosphere. Thermocouples made of iridium and iridium alloy have only recently come into use for temperature measurements above 2800° F.

**For further information circle No. 918 on literature request card, p. 36-B.**

### *Positioner*

A new unit for positioning both the weldment and the automatic welding head has been announced by C. B. Herrick Mfg. Corp. It is a combination mast-ram positioner. The work



may be positioned or rotated under the welding head which is adjustable vertically and horizontally. Motorized, variable speed, lateral travel on the ram is available with the automatic head mounted on a travel carriage. Another feature is 360 deg. rotation of the mast and ram.

**For further information circle No. 919 on literature request card, p. 36-B.**

### *Finishing Compound*

A new barrel finishing compound designed to produce smooth finishes on light metal die castings has been announced by Minnesota Mining and Manufacturing Co. The compound will remove light machine marks and leave a fine surface finish, with a minimum of stock removal. The compound contains a very fine mineral grain which gives it a mild abrasive action, improving the quality of subsequent plating and ball burnishing operations.

**For further information circle No. 920 on literature request card, p. 36-B.**

### *Coolant*

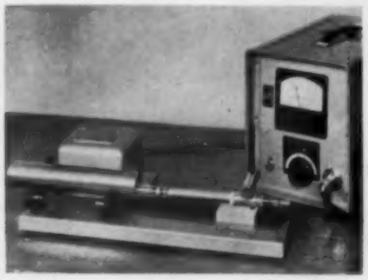
Johnson's Wax Co. has announced their new water soluble cutting fluid which will not cause foul coolant odors for two months. TL-131 is used in the same way as any conventional water soluble coolant. The machine

should be cleaned and then completely recharged with TL-131. TL-131 does not require the use of formaldehyde or bactericides before it is placed in a machine.

**For further information circle No. 921 on literature request card, p. 36-B.**

### *Profilometer*

Micrometrical Mfg. Co. has announced a device for taking profilometer roughness measurements around the circumference of tubing, round bar stock and other cylindrical pieces. The piece to be measured is placed on



two pairs of rollers. One roller is driven by belt from a constant-speed motor in the housing, and rotates the work at a surface speed of 0.3 in. per sec. The roughness measurement is made by a type LA tracer. The tracer is supported by an arm and remains stationary while the work rotates beneath it. The arm is attached to a vertical post on a horizontal slide, to permit adjusting the height of the tracer, for different work diameters, and the lengthwise position of the tracer, for measuring at different locations along the work.

**For further information circle No. 922 on literature request card, p. 36-B.**

### *Torsion Tester*

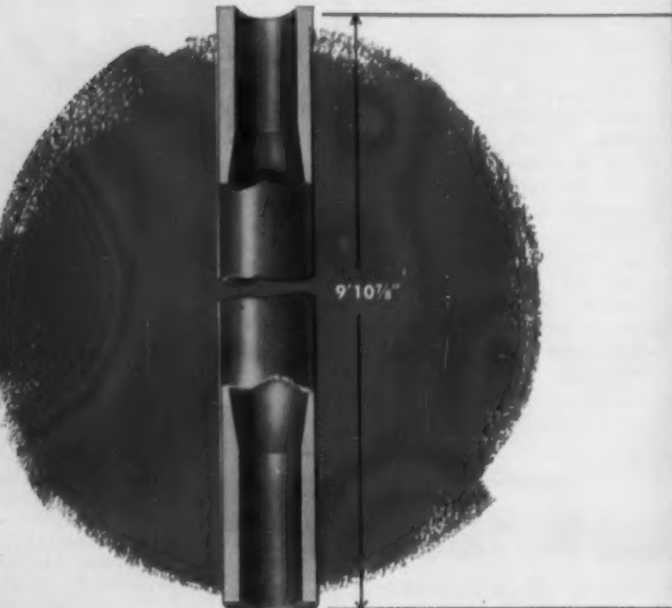
A 200,000 in.-lb. torsion testing machine which loads and indicates torque in both directions of rotation has been announced by the Tinius Olsen Testing Machine Co. This double torsion tester continuously loads and reverses with only one set of grips, subjecting the specimen to a twist of "X" degrees alternately in both directions until it fractures or until the machine is stopped by the operator. The electronic Selectorange indicating system is coupled directly to the double weighing system, and a light on the control panel indicates load direction. It has a full dial scale for each of three capacity ranges in both clockwise and counter-clockwise rotations.

**For further information circle No. 923 on literature request card, p. 36-B.**

OSTUCO TUBING

# REDUCED DRILL ROD WEIGHT 20%

TO GIVE RIGS A LONGER REACH!




**OSTUCO PROJECT REPORT . . . CHICAGO PNEUMATIC TOOL CO.**

A well known method of test drilling is faster and more efficient with lightweight drill rod manufactured from 9' 10⅞" sections of internally upset OSTUCO Tubing. Heavy-wall tubing once was considered necessary to prevent breakage at the threaded joint—but its weight shortened drilling depth of more practical, semi-portable drill rigs.

With internally upset OSTUCO Tubing, rod ends are thicker than the tube body which provides needed strength with 10½ pounds less weight per section. Dead weight eliminated in the tube body amounts to over 2½ tons per 5000 feet of drilling depth. This permits the use of semi-portable drilling equipment that handles much longer rods because of their lighter weight.

This application may spark an idea for you . . . how to save production time and cost with versatile, *special-quality* OSTUCO Tubing. And you'll be interested in OSTUCO's unique *single-source service*, where one order takes care of all details. Write for catalog, "Ostuco Tubing," or send your blueprints for prompt quotation.

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—*Fabricating and Forging*

**OHIO SEAMLESS TUBE DIVISION**
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*Birthplace of the Seamless Steel Tube Industry in America*
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117 Liberty Street, New York 6, New York

# WHAT'S NEW IN MANUFACTURERS' LITERATURE

**939. Abrasive**
Bulletin on aluminum oxide barrel finishing compound for tumbling and precision finishing. *Simonds Abrasive Co.*

**940. Alloy Steel**
40-page book on applications of heat treated, special alloy steel. *Jones & Laughlin*

**941. Alloy Steel**
207-page book gives more than 50 complete case histories of alloy steel usage. *Climax Molybdenum*

**942. Alloy Steel**
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

**943. Alloy Steel**
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

**944. Alloy Steel**
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

**945. Aluminum**
Chart describes new aluminum designation system developed by the Aluminum Association. *Peter A. Frasse*

**946. Aluminum**
New 16-page brochure on mill products and how to use them. Wrought aluminum alloy selection guide, properties of various aluminum mill products and applications. A casting alloy selection guide. *Reynolds Metals*

**947. Aluminum Coating**
Article on hot dip coating of ferrous metals with aluminum and aluminum alloys from "Tips and Trends". *Ajax Electric*

**948. Aluminum Die Castings**
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

**949. Aluminum Welding**
Data on chemical composition of aluminum welding rods and electrodes. *Arcos Corp.*

**950. Analysis of Nickel Alloys**
52-page Technical Bulletin T-36, "Methods for Chemical Analysis of Nickel and High-Nickel Alloys". *International Nickel*

**951. Annealing Furnaces**
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever*

**952. Atmosphere Furnace**
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

**953. Atmosphere Furnaces**
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

**954. Atmospheres**
12-page booklet on design and use of special atmospheres for industrial furnaces. *Continental Industrial Engineers*

**955. Automatic Polishing**
14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. *Murray-Way*

**956. Barrel Finishing**
32-page handbook on compounds for descaling, deburring, coloring, metal cleaning and rust inhibition. *Lord Chem.*

**957. Beryllium Copper**
16-page booklet on applications and properties of beryllium copper. *Beryllium*

**958. Bimetal Applications**
36-page booklet, "Successful Applications of Thermostatic Bimetal", describes 22 uses and gives engineering data. *W. M. Chace*

**959. Blackening Compounds**
Bulletin on blackening compounds for ferrous alloys to AMS Spec 2485. *Swift Industrial Chemical*

**960. Blast Cleaning**
4-page bulletin on nonmetallic, dustless mineral shot for blast cleaning. *Baldwin-Hill Co.*

**961. Boron Additive**
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

**962. Brass Tubing**
Bulletin on seamless, brazed and lock-seam tubing in brass and copper. *H & H Tube and Mfg.*

**963. Brazing**
New bulletin No. 67 on low-temperature brazing. Case histories. *Handy & Harman*

**964. Brazing Stainless Steel**
Illustrated booklet, "Bright Annealing, Hardening and Brazing Stainless Steel", describes conveyor furnace and bright brazing alloy. *Sargeant & Wilbur*

**965. Bronze Bearings**
New brochure on bearing bronze. *American Smelting and Refining Co.*

**966. Calibrating Machine**
Bulletin 115 on calibrating system for accurate measurement of mechanical forces. *Morehouse Machine*

**967. Camera**
Bulletin on macro camera for photographing at 1.25 to 24.50 times. *Chapman Laboratories*

**968. Carbon and Graphite**
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical, process fields. *National Carbon*

**969. Carbon Control**
Bulletin C-22 and reprint on Carbotronik for automatic control of carbon potential of atmospheres. *Ipsen*

**970. Carbon Control**
New 12-page catalog TD4-620 (2) on Microcarb atmosphere control for control of carbon potential in Homocarb furnaces. *Leeds & Northrup*

**971. Carbon Dioxide**
Booklet gives uses of carbon dioxide in industry. *Liquid Carbonic Corp.*

**972. Carbon Steel Castings**
Data folders on four types of carbon steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

**973. Carbonitriding**
28-page booklet on nature of process, furnaces, atmospheres, parts carbonitrided and properties. *Armour Ammonia*

**974. Carbonitriding**
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

**938 Aluminum Casting Alloys**

ASTM, SAE, Navy, Federal, Military, AMS and Federated specifications for ingots, sand castings, permanent mold castings and die castings of aluminum alloys are thoroughly cross indexed in the last half of this


60-page book. The first section discusses the effect of copper, silicon, magnesium, manganese, iron, zinc, nickel and titanium on aluminum, gives methods of heat treating, and discusses problems involved in casting aluminum alloys by sand or permanent mold or die casting methods.—*Federated Metals*

**975. Casehardening**
32-page booklet on casehardening of steel by nitriding. *Armour Ammonia Div.*

**976. Castings**
New 16-page booklet, "Cast to Outlast Destructive Service", gives latest information and case histories on use of sand, centrifugal and precision investment castings. *International Nickel Co.*

**977. Centrifugal Castings**
Booklet on spun centrifugal castings of bronze for liners, rings, rolls, sleeves, bushings. *American Non-Gran Bronze*

**978. Chromate Finishing**
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

**979. Cleaners**
Bulletins on di-phase cleaners, specifications, equipment, advantages. *Solventol*

**980. Cleaning**
24-page booklet on use of solvent detergents for removing carbon, grease, dirt and paint. *Oakite*

**981. Cleaning and Finishing**
18-page booklet presents 40 frequently met applications in which wet abrasive blasting can be used. *American Wheelabrator & Equipment*

**982. Cleaning Compound**
Bulletin B-6 on water displacing compound for producing unspotted, dry surfaces. *Apothecaries Hall*

**983. Cold Finished Steel**
16-page booklet on 10 grades of cold finished steels. Analysis, machinability, heat treatment, wear resistance. *Jones & Laughlin*

**984. Compressors**
12-page data book 107-D gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

**985. Controlled Atmospheres**
Bulletin on Dewpointer for reading of atmosphere in field and laboratory. Readily portable, operating on a.c. or enclosed battery. *Illinois Testing Labs.*

**986. Controllers**
46-page Bulletin 1120 on pneumatic control and transmission systems. Pneumatic controllers and how they work. *Minneapolis-Honeywell*

**987. Copper Alloys**
40-page book on eleven copper alloys. Properties, cleaning, annealing. *Seymour Mfg.*

**988. Copper Nickel Alloys**
8-page bulletin on composition, properties and applications of series of 12 copper-nickel-base alloys available in cast form. *Waukesha Foundry*

**989. Corrosion Resistance**
32-page brochure on causes of corrosion and means of combating them. Choice of materials for condenser tubes. *Revere Copper & Brass*

**990. Cut-Off Wheels**
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

**991. Cutting Oil**
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service*

**992. Deburring**
Catalog of tools for burr removing and chamfering of drilled holes, inside tubing, ends of rods. *Nobur Mfg. Co.*

**993. Degreasing**
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

**994. Degreasing**
40-page book on properties and use of trichlorethylene. Methods of handling and safety measures. *Niagara Alkali*

**995. Degreasing**
12-page booklet on what you should know about vapor degreasing. Principles of process, and various types of degreasers. *Metalwash Machinery*

**996. Descaling**
Brochure on sodium hydride descaling, its uses, advantages, typical reactions and necessary equipment. *Ethyl Corp.*

**997. Dew-Point Recorder**
Bulletin 407 and Data Sheet AED 340-7 on dew-point systems for recording or controlling. *Foxboro*

**998. Die Casting**
Booklet on "High-Speed Precision Die Casting Machines". *Reed-Prentice*

**999. Die-Casting Machines**
Bulletin on new die casting machine with new clamp design and injection end. *Hydraulic Press Mfg. Co.*

**1000. Die-Casting Machines**
Case histories of companies using various types of die-casting machines. *Kux Machine*

**1001. Dielectric Heating**
New bulletin on dielectric heaters and their advantages. *Allis-Chalmers Mfg.*

**1002. Dryers**
24-page bulletin No. 222 shows installations of air drying equipment in various industries. *Pittsburgh Lectrodryer*

**1003. Electric Furnaces**
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

**1004. Electric Furnaces**
Booklet on four types of electric heating elements and their methods of mounting. *Holcroft*

**1005. Electric Furnaces**
8-page booklet on belt conveyor electric furnaces for bright hardening. *Westinghouse Electric Corp.*

**1006. Electric Melting**
Bulletin 527 on compact arc furnace. Melt time and power consumption for four alloys. *Detroit Electric Furnace*

**1007. Electrode Control**
4-page bulletin 162 on system of hydraulically positioning arc furnace electrodes. *Askania Regulator*

**1008. Electroforming**
Bulletin on production of intricate parts and precision components by the electroforming process. *Bart Labs.*

**1009. Electron Microscope**
20-page brochure describes in detail ten case histories in which the electron microscope has been at work solving problems of development and control in industrial laboratories. *RCA*

**1010. Extrusion Presses**
8-page bulletin on aluminum extrusion presses describes the process and presses at work. *Watson-Stillman*

**1011. Filters**
Bulletins on full flow, multi-cartridge and bulk refill models of oil filters. *Houdaille-Hershey of Indiana*

**1012. Filters**
8-page bulletin on dimensions and capacities of industrial filters. *Industrial Filtration Co.*

**1013. Finishing**
52-page book "Advanced Speed Finishing" describes equipment for deburring and finishing. *Almco Div.*

**1014. Finishing**
Catalog A-654 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon*

**1015. Flame Hardening**
20-page booklet on precision flame hardening machine with electronic control. Details of operation and applications. *Cincinnati Milling Machine*

**1016. Flaw Detection**
New 12-page bulletin on location of flaws by the dye-penetrant inspection method. *Turco Products*

**1017. Flow Meters**
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g*

**1018. Fluoroscopy**
12-page booklet on fluoroscopy for non-destructive internal inspection. Explains image amplifier. *Westinghouse Electric, Industrial X-Ray Dept.*

**1019. Forging Hammers**
24-page brochure describes construction and use of steam drop hammers. *Erie Foundry*

**1020. Forgings**
Catalog on forgings from copper, copper alloys and aluminum alloys. Compositions of alloys, properties, electrical conductivity, tolerances and specification numbers. *Scovill Mfg., Forgings Div.*

**1021. Forgings**
New bulletin on melting, forging, rough machining and heat treating facilities. *National Forge & Ordnance*

**1022. Forgings**
Folder on large forgings of carbon and alloy steel. *Struthers Wells Corp., Titusville Forge Div.*

**1023. Forming Dies**
Folder on styles of forming dies for stainless heads—in wide range of sizes and gages. *Carlson*

**1024. Freezer**
Data on chest for use down to −95° F. for production use and testing. *Revco*

**1025. Furnace Belts**
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

**1026. Furnace Charging**
12-page brochure on eight models of charging machines for heating and melting furnaces. *Salem-Brosius*

**1027. Furnace Controls**
44-page condensed catalog of controls for industrial furnaces and ovens. *Minneapolis-Honeywell Regulator Co.*

**1028. Furnace Controls**
New edition of specifications catalog for furnace and oven control instruments and accessories. *Bristol Co.*

**1029. Furnace Controls**
22-page booklet on instruments and controls for heat treating furnaces. *Hays Corp.*

**1030. Furnaces**
Bulletin 451 and 341 on pit-type convection furnaces and multi-range convection furnaces. *Hevi Duty*

**1031. Furnaces**
Bulletin on reverberatory furnaces for aluminum, aluminum alloys and die casting metals. *Eclipse Fuel Eng.*

**1032. Furnaces**
High temperature furnaces for temperatures up to 3000° F. are described in bulletin. *Carl-Mayer Corp.*

**1033. Furnaces**
Data on electric furnaces of top or side loading types. *Lucifer Furnaces*

**1034. Furnaces**
Bulletin 435 on furnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated. *W. S. Rockwell*

**MAINTENANCE COSTS**

# *less than 3¢ per hour*

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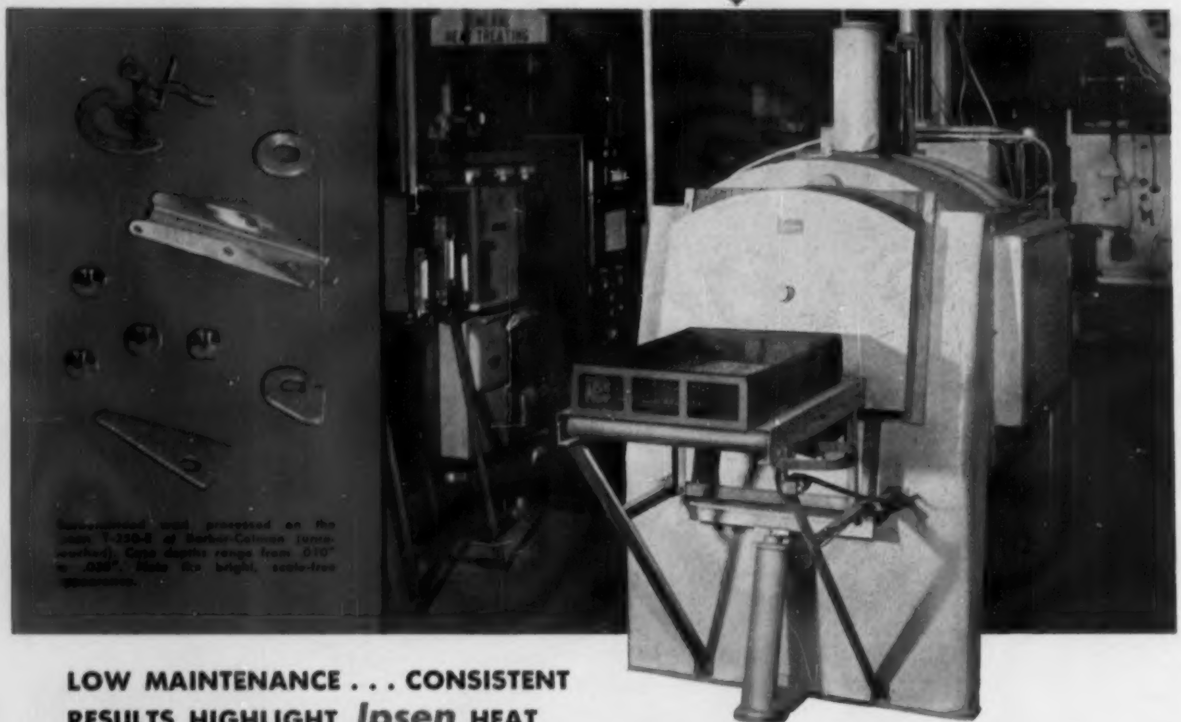


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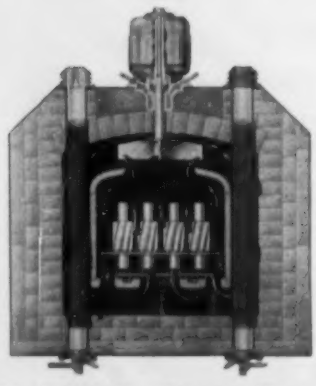
Total maintenance expense . . . $395.56. Total hours of operation . . . 13,200. Type of work . . . 65% bright carbonitriding, 20% bright carburizing, all other, 15%. ***Less than 3 cents per hour for maintenance.*** That's the report from the Barber-Colman Heat Treating Department on this Ipsen T-250-E Furnace since its installation.

Now . . . Ipsen's latest 100% Forced Convection design cuts low maintenance costs even more.



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AUTOMATIC **Ipsen** HEAT TREATING UNITS

**1035. Furnaces, Heat Treating**
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

**1036. Furnaces, Heat Treating**
Bulletin on fuel and electric furnaces for heat treating. *Dempsey*

**1037. Gamma Radiography**
8-page catalog on gamma-ray radiography with radioactive cobalt 60 and iridium 192. *Mitchell Radiation Products*

**1038. Gas Analysis**
Data on gas purity and trace impurity analyzer. *Gow-Mac Instrument Co.*

**1039. Gas Pilots**
Bulletin 151-155 on specifications and instructions for manually or electrically ignited pilots. *North American Mfg.*

**1040. Graphite**
New 20-page brochure on significance of graphite as electrodes, anodes, molds and specialties in electrometallurgy and electro-chemistry. *Great Lakes Carbon*

**1041. Graphite Molds**
Data on two types of molds for casting magnesium, steel, copper, brass and other metals. *National Carbon*

**1042. Graphitic Tool Steels**
48-page booklet on heat treating data, properties and 46 specific applications of graphitic tool steel. *Timken*

**1043. Handling Devices**
Pamphlets on clamps for lifting and handling. Their application to various industries. *Merrill Bros.*

**1044. Hard Surfacing**
New 16-page book on "Electrolizing" tells what the process is, how it can be used, and advantages. *Electrolizing Corp.*

**1045. Hardness Tester**
4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

**1046. Hardness Tester**
Literature on Brinell testing machines. *Detroit Testing Machine Co.*

**1047. Hardness Tester**
20-page book on hardness testing by Rockwell method. *Clark Instrument*

**1048. Hardness Testers**
20-page bulletin on models, applications and how to use superficial harness testers. *Wilson Mechanical Instrument*

**1049. Hardness Testing**
8-page catalog B-953 on principles and standards of Brinell hardness testing, and types of machines. *Steel City Testing Machines*

**1050. Heat Exchanger**
Bulletin 124 on heat exchanger for cooling water, oil and other liquids and gases in many industries. *Niagara Blower*

**1051. Heat Treating**
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

**1052. Heat Treating**
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

**1053. Heat Treating Baskets**
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

**1054. Heat Treating Fixtures**
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

**1055. Heat Treating Pots**
Bulletin 110 gives data on sizes and shapes of cast nickel-chromium solution pots. *Fahralloy*

**1056. Heating Elements**
24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div.*

**1057. Heating Light Metal**
New booklet on ovens for heat processing of aluminum, magnesium and titanium. *Michigan Oven*

**1058. High-Alloy Castings**
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

**1059. High-Strength Bronze**
12-page booklet on telnic bronze with high strength, high hardness, good machinability, age hardenability, corrosion resistance. *Chase Brass*

**1060. High-Temperature Alloy**
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

**1061. High-Temperature Steels**
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U. S. Steel*

**1062. High-Vacuum Pumps**
Data sheet on physical dimensions, operating data and performance curves for high-vacuum oil diffusion pumps. *Consolidated Vacuum Corp.*

**1063. Identifying Alloys**
Booklet of procedures for rapid identification of more than 125 metals and alloys. *International Nickel*

**1064. Identifying Stainless**
Cardboard chart outlining systematic method for rapid identification of unknown or mixed stocks of stainless steels. *Carpenter Steel*

**1065. Indicator**
Bulletin 61-H on self-balancing temperature indicator. *Thermo Electric*

**1066. Induction Heating**
36-page catalog on high-frequency induction heating. *Lepel*

**1067. Induction Heating**
Bulletin 1440 on system for safety control of induction heating through use of components built into every unit. *Lindberg Engineering*

**1068. Induction Heating**
60-page catalog tells of reduced cost and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

**1069. Induction Heating**
"Induction Heating" . . . presents case histories of increased production, reduced space, lower costs. *Westinghouse*

**1070. Industrial Fans**
Catalogs on various kinds of industrial fans — exhaust, multiblade, backward curve, for high temperatures. *Garden City Fan*

**1071. Insulation**
40-page industrial products catalog on insulations, refractory products, and others. *Johns-Manville*

**1072. Interference Microscope**
Bulletin B-602 describes new instrument for fast nondestructive examination and photography for wave-length measuring of surface finishes in the order of one millionth of an inch down to 300 Angstroms. *Boder Scientific Co.*

**1073. Iridium Radiography**
8-page booklet on industrial radiography with iridium 192. Method, advantages, equipment. *Gamma Corp.*

**1074. Laboratory Furnace**
Box furnace with cooling chamber for use to 3100° F. described in bulletin GEA-4713. *General Electric*

**1075. Laboratory Furnaces**
Folder describes and illustrates tubular furnace for use in tensile testing, and control panels. *Marshall Products*

**1076. Laboratory Furnaces**
26-page, "Construction of Laboratory Furnaces," contains many diagrams, charts, tables and information on how to construct furnaces. *Norton*

**1077. Light Metal Heating**
8-page bulletin on furnaces and equipment for melting and heat treating light metals. *Surface Combustion*

**1078. Lubricant**
Literature on anti-seize molybdenum disulfide lubricant. *Bel-Ray*

**1079. Lubricant**
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Corp.*

**1080. Machining Alloy Steels**
24-page bulletin on economical combination of microstructure, tool form, cutting speed and feed for each machining operation. *International Nickel*

**1081. Machining Titanium**
Four discussions of methods, problems, chip formation in grinding and machining titanium. *Cincinnati Milling Machine*

**1082. Magnesium**
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

**1083. Magnesium**
Dimensions, analyses, property data of magnesium plate and sheet. *Brooks & Perkins*

**1084. Magnesium Extrusions**
36-page bulletin gives values for moment of inertia, section modulus and radius of gyration of bars, tubing, angles, channels, tees, zees and other sections. *Dow Chemical*

**1085. Magnesium Finishing**
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(*Continued on p. 36A*)

(Continued from page 34)

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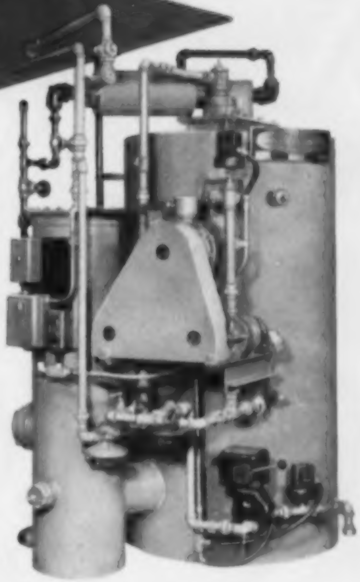

Holcroft has designed a radically-different exo-endothermic gas generator. Designed not only for the batch furnace but for other furnaces as well, the generator can produce gas atmospheres between the limits of perfect combustion and modified "302." At the latter setting, the gas generated has two main differences from a standard AGA Type 302 gas. The first is very much lower dewpoints—as low as minus 50 deg. F. with no detectable amounts of methane. In addition, the gas produced has an approximate 50% lower hydrogen content. This means that for a given carburizing potential, less hydrocarbon addition is necessary. The lower percentage of hydrogen is an added safety feature. The Holcroft process is covered by U. S. patent No. 2,589,810.

A slight adjustment at the generator can produce a non-explosive atmosphere to perform heat treating cycles below the explosive limits required for atmosphere tempering, annealing, and stress relief of ferrous alloys as well as hardening, annealing and tempering of non-ferrous alloys.

The new generator is an extremely compact unit (but 20 square feet of floor space is required.) The total gas used can be adapted to many manufacturing requirements.

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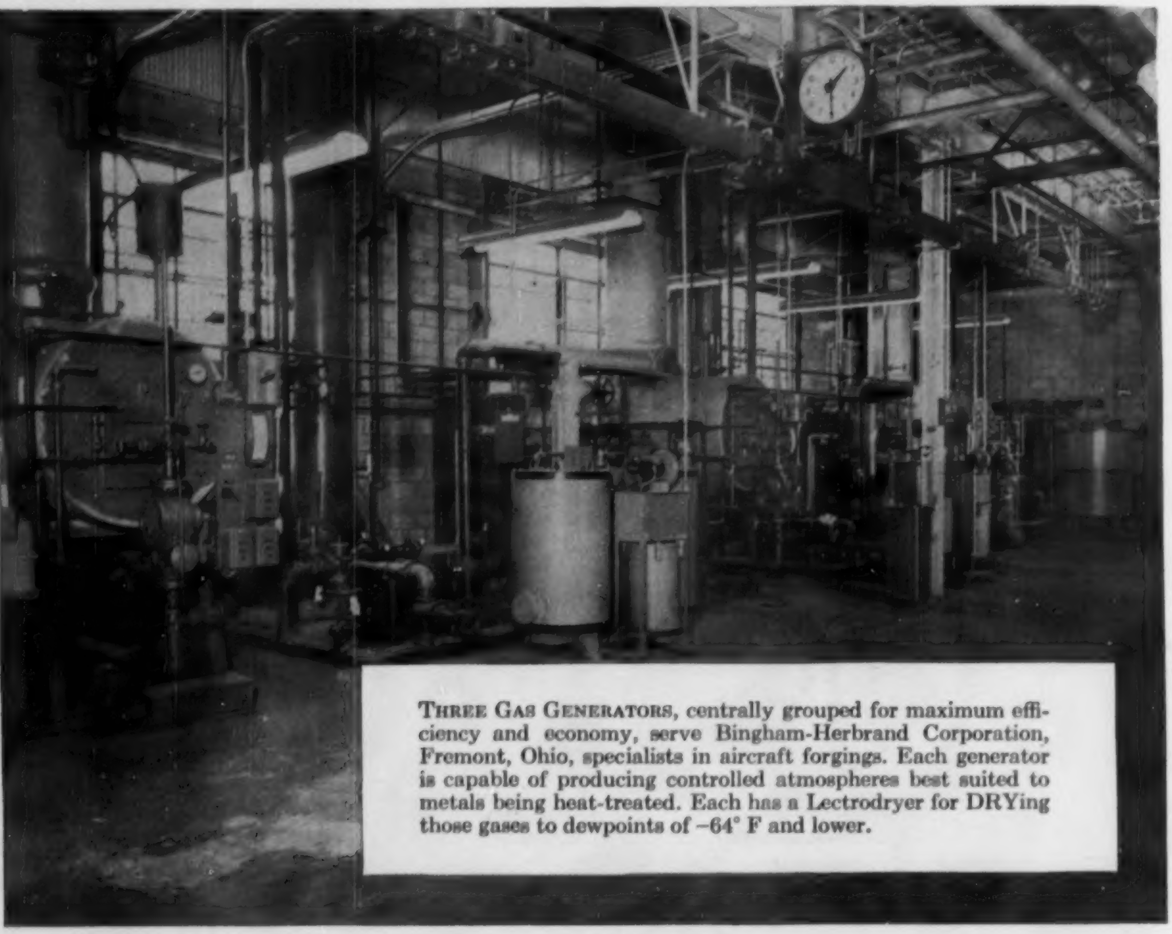

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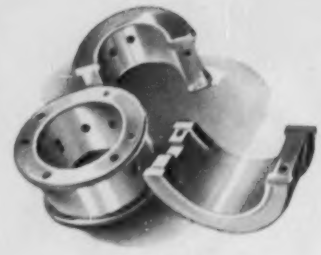

These new tin-aluminum bearings (up to 30% tin) are several times stronger than babbitt.

Tests show that a new tin-zinc plating alloy gives unusual corrosion protection to steel.

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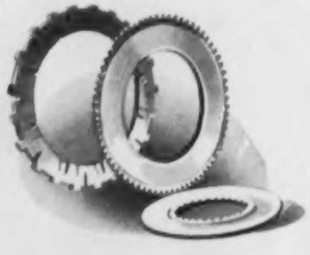

Tin is an important component of many sintered metal parts, such as these clutch facings.

And organotin compounds are the best stabilizers known for polyvinyl chloride plastics.

These are just six of hundreds of new ways Straits Tin is being used today. No other metal has tin's capacity for making other materials more efficient.

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A tin coating on the fin coils of air-conditioning units helps prevent corrosion and odor accumulation. Modern engine pistons are often plated with tin to reduce friction between the piston and the cylinder liner. And a new way of electroplating bright tin-nickel offers for the first time a successful alternate to chrome on nickel-copper. Tin-nickel is both more corrosion resistant and more attractive than chrome. And it helps save scarce nickel.

Tin, of course, is not scarce. Nor is it likely to be in the future. Over one-third of the world's tin comes from Malaya. A great deal is there. And Malayan tin producers want to export it as much as American industry wants to use it.

Malaya is the keystone of Southeast Asia. With Malaya steadily winning its war against Communist guerrillas—with the new Manila Treaty and new U.S. Economic Aid Plans promising increased security against Communist infiltration in this vitally important area—American industry can count on a supply of tin fully as dependable as the supplies of other materials that are being produced in the Free World.

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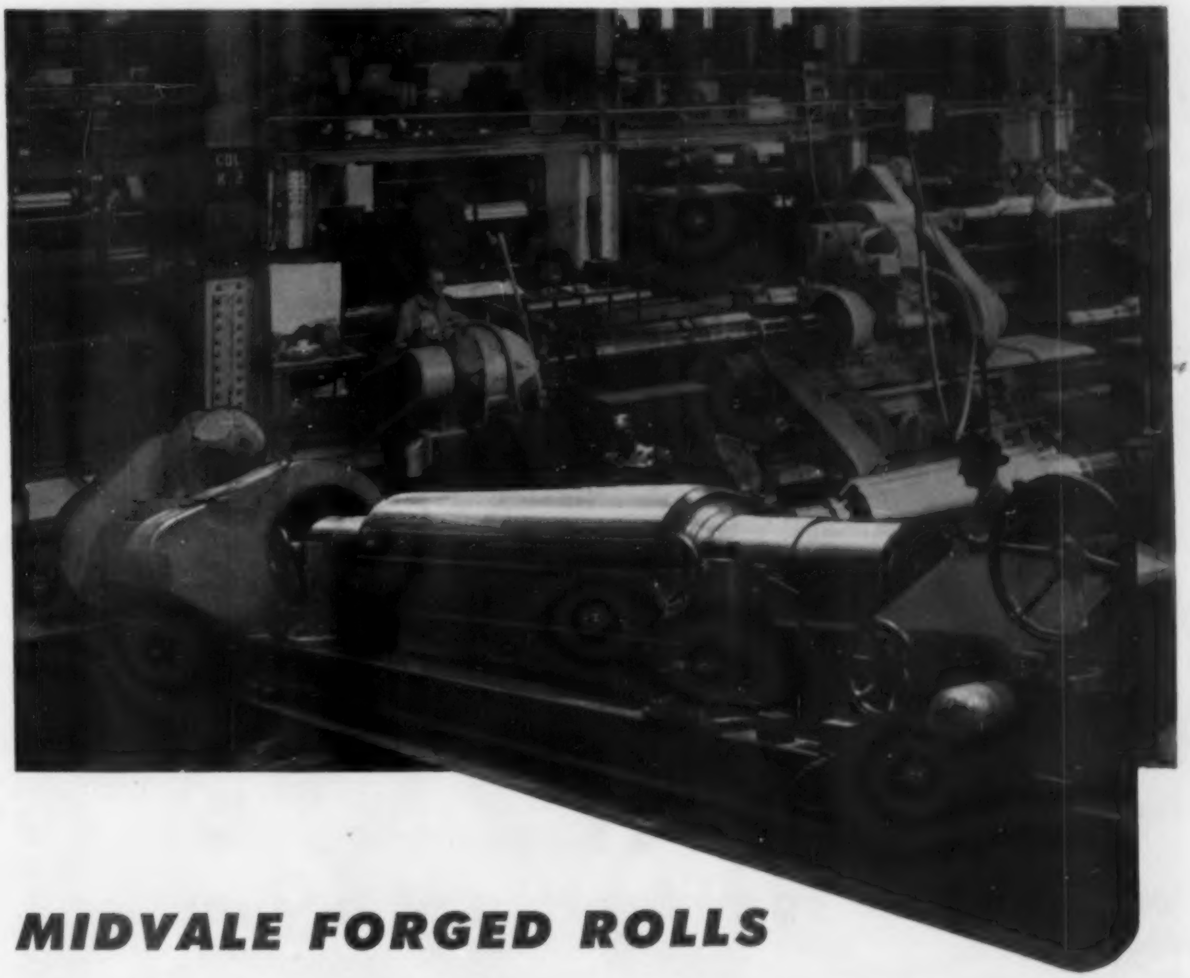

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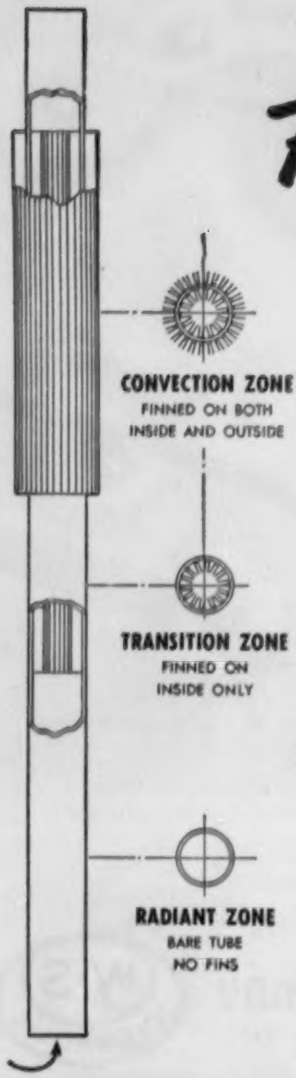


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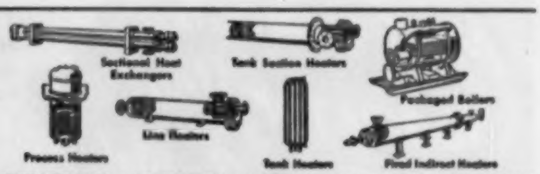


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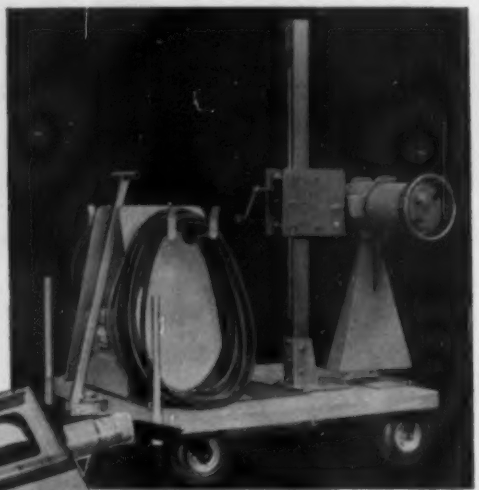

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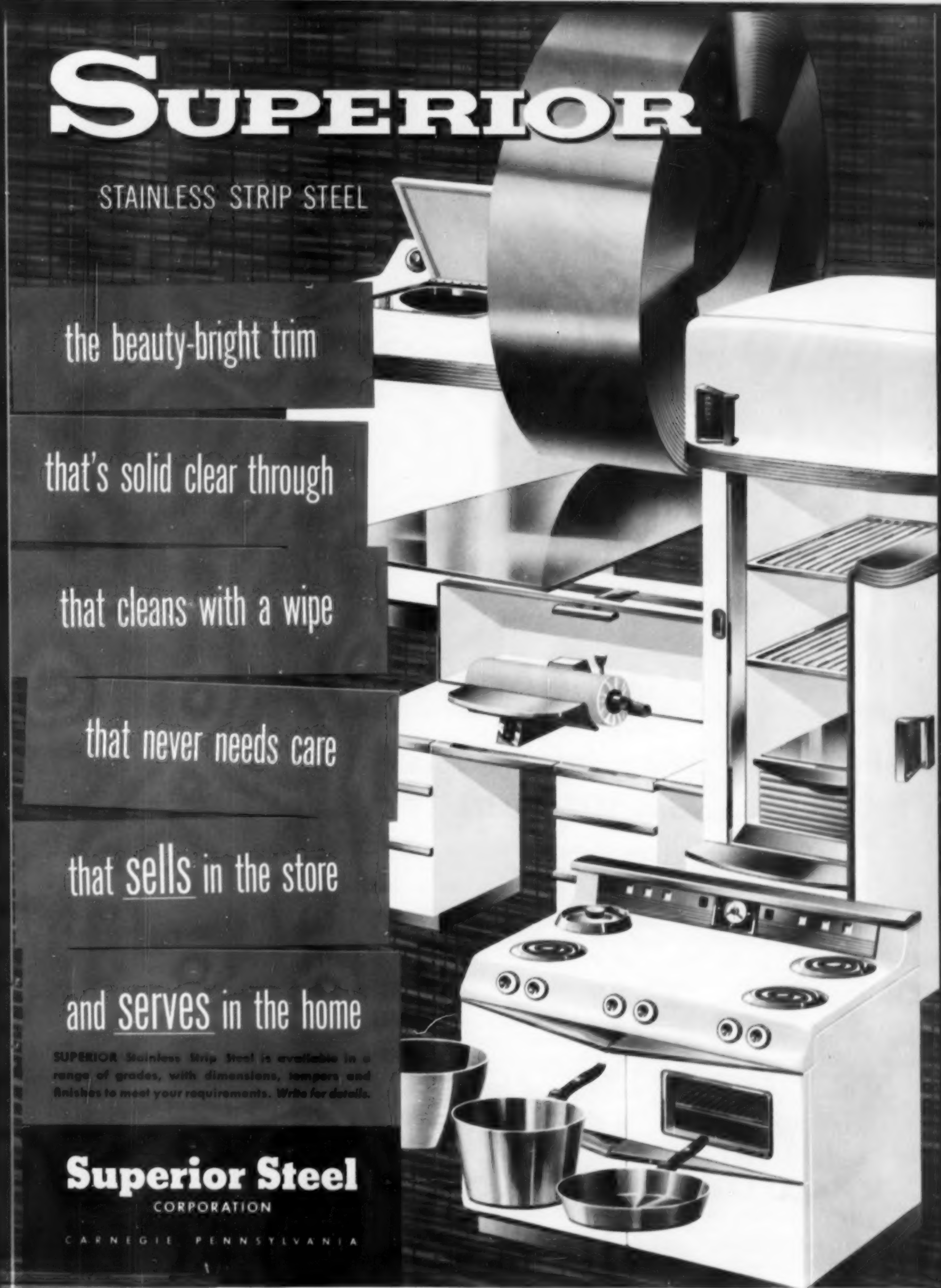
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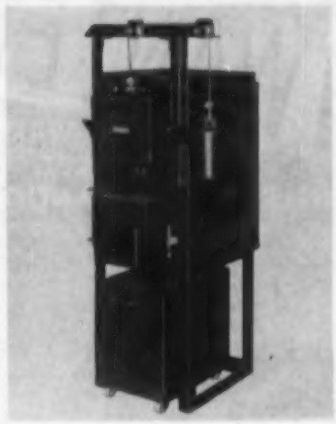

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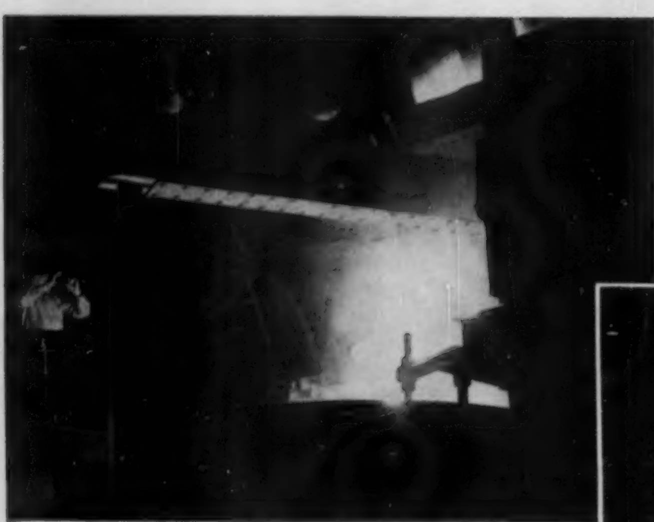

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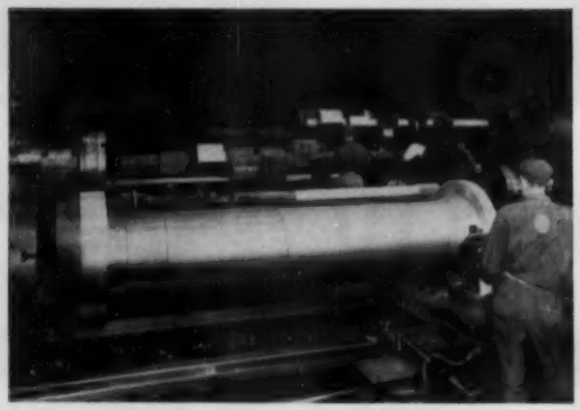

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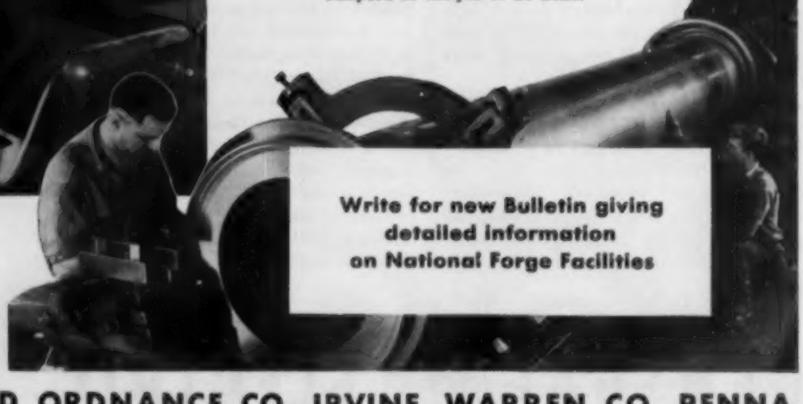


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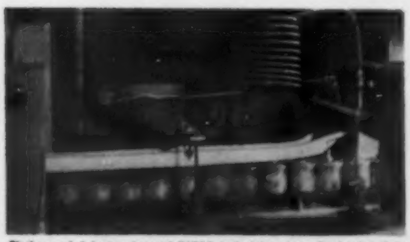

Photos and data courtesy of FASCO Industries, Inc., Rochester, N.Y.

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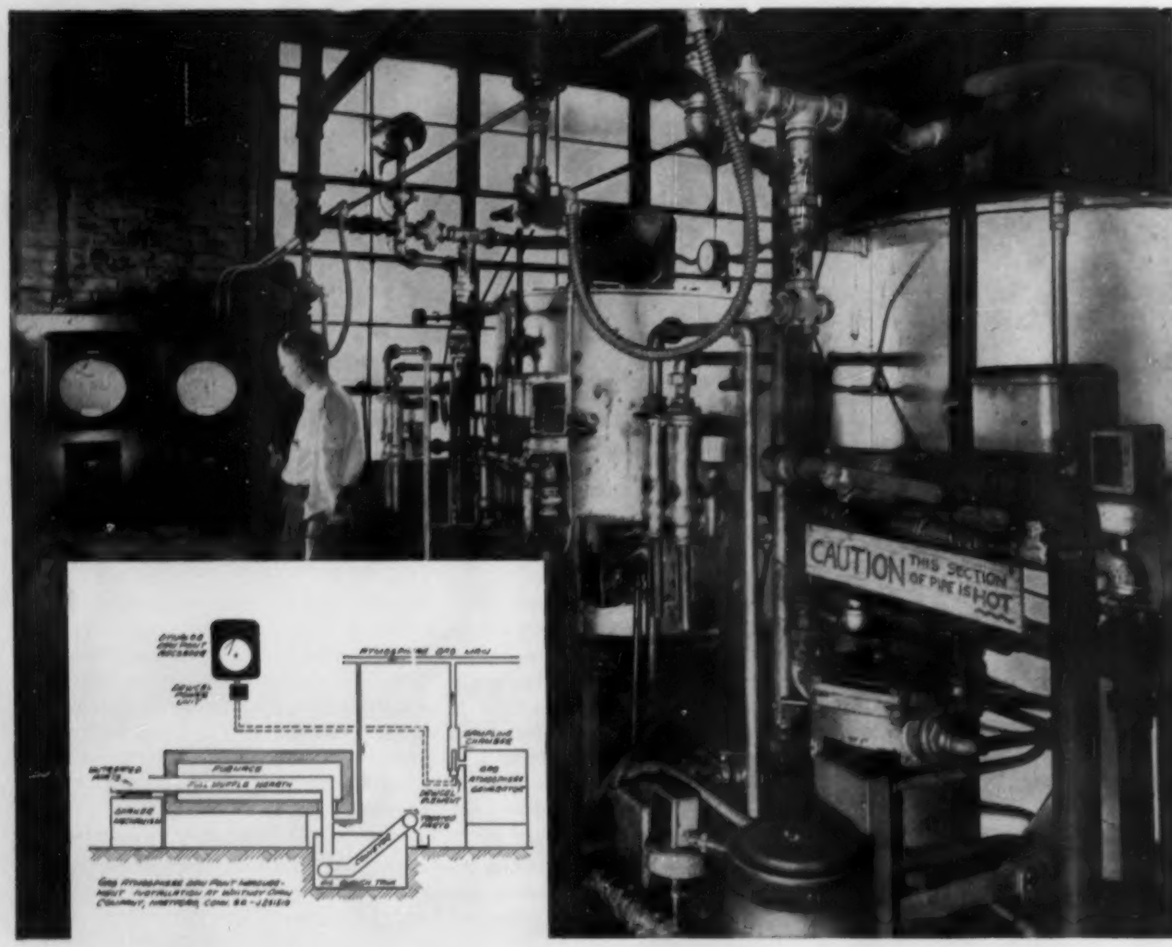


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**Prompt technical help** is furnished to Fairchild by Du Pont Technical Representative "Chris" Christiansen (left), shown here with Mr. Robert McKie.

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Metal Progress

April . . . 1955

# Progress Report on Cermets

*By FRANK W. GLASER**

**Severe specifications by the armed forces and the jet engine builders have eliminated many combinations of hard particles and metal binders – the "cermets" – from gas turbine construction. However the following three classes of material may be able to carry the working temperature progressively up to 2100° F. – nickel aluminides, titanium carbide with metal binder, and the borides of chromium-molybdenum.**

FOLLOWING World War II, it became apparent that increased jet aircraft speeds and higher engine efficiencies required new materials for use up to 2100° F., to supersede the nickel-base and cobalt-base alloys proven to be satisfactory for operating temperatures up to 1600° F. In the last eight to ten years a great research effort has been made to provide such materials, both by industrial and by governmental laboratories. It is the present aim to evaluate briefly the results so far achieved, principally within the last five or six years, subject to the limitations that much governmental work is still secret or restricted, and that the author is far more familiar with the work in his own organization and its subsidiaries than with that of others.

The word "cermet" seems to have been manufactured from the words "ceramic" and "metal." It is sufficiently accurate for this article, if it is understood to mean, usually, a composite material, for the time being *in the form of testable shapes only*. Also that the material combines a hard phase – not necessarily a true ceramic – with a metallic binder. These two distinct phases are quite different in hardness and melting points. We therefore start with

### Metallurgical Considerations

Most cermets are produced by powder metallurgy and related techniques. Large numbers of tiny particles in contact will insure relatively rapid diffusion while sintering or hot pressing. Unless metallurgical equilibrium is attained in the solid state the mechanical properties of test pieces will scatter so much that such a composite body cannot be evaluated.

For example, the room temperature properties of chromium boride sintered with 15% of nickel are quite interesting – 123,000 psi. modulus of rupture and A-87.4 Rockwell hardness – and are of the same magnitude as those for today's acceptable cermets. However, when exposing samples for 48 hr. in air at various temperatures a different aspect appeared. Up to 1600° F. there was no reportable change; samples tested at 1725 and 1850° F. acquired a slight coating of green oxide. After 48 hr. at 1900° the hardness dropped to A-80, and an "unexpected" liquid phase

*Vice-President, American Electro Metal Corp., Yonkers, N.Y.

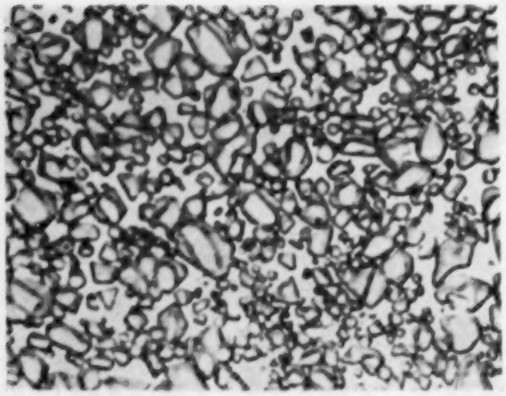


*Fig. 1 – Microstructure of a Typical Cermet Based on Titanium Carbide. Second phase (binder) is 80-20 Ni-Cr alloy. Mixture: 50% carbide, 50% binder. 1500 ×*

appeared on the surface (later identified as a Cr-Ni-B eutectic). 48 hr. at 2050° F. caused the sample to warp and colored it darkly. This low-melting phase is probably also responsible for the low stress-to-rupture strengths:

| Temperature | Rupture Time, Psi. 10 Hr. | 100 Hr. | 500 Hr. |
|---|---|---|---|
| 1500° F. | 6000 | 4700* | 4000 |
| 1600 | 4000 | 2700 | 2000 |

Once it was recognized that hard metal phases could not be combined empirically with other metals without thorough knowledge of the ternary or even quaternary systems involved, a very important lesson had been learned. Even though tungsten carbides had long been "bonded" successfully with cobalt for cutting tools, when we tried to extrapolate that experience to the "cementing" of other hard phases for use at high temperature, we made a time-consuming mistake.

Of the carbides readily available, only titanium carbide and chromium carbide appeared of interest as hard metal phases for use in a cermet body. Tungsten carbide and tantalum carbide were both heavy and poor in oxidation resistance. The carbides of columbium, vanadium, zirconium, and molybdenum had to be discarded because of high cost or poor oxidation resistance. Table I lists the respective solubilities of some of these for the binder metals cobalt, nickel and iron. Of these only TiC-base cermets became important as a high-temperature material.

**Eutectic Binding** – In view of the importance of metallurgical equilibrium between the divergent phases in a successful cermet, certain researchers introduced the notion of "eutectic binding", thereby attempting to take advantage of supposedly favorable phase diagrams. Eutectic compositions were synthesized to introduce liquid phases that would aid the diffusion process during sintering. Such neat tricks required thorough preliminary studies of equilibrium diagrams prior to actual fabrication of a new cermet body. Although such diagrams for the W-C-Ni, W-C-Co, or the Ti-C-Ni systems appeared in the literature only after cemented tungsten carbide tools had been on the market for many years and the Ti-C-base cermets had become well known to industry, phase diagrams of the transition metals* and the elements boron or silicon had to precede the new cermets. As of today, a great amount of structural analysis by X-ray diffraction, as well as thermal analyses to determine phase relations, has brought the borides into a relatively well-known group of refractory compounds. Eutectic binding techniques were used to produce bonded zirconium and chromium borides. Titanium, tungsten and molybdenum borides have also been mentioned for certain industrial applications.

The metallurgy of the transition metal silicides has received equal attention during recent years and work on these cermets is now facilitated by the availability of good equilibrium diagrams.

**Aluminides** have recently been mentioned for high-temperature applications – especially nickel aluminide. It might not be considered a cermet, in the sense defined at the outset, for it appears to be a single-phase body. There are not enough

*Figure for cast Vitallium would be 20,000 psi.

*The transition metals, so-called, are elements No. 21 to 28 in the first long series in the periodic table, No. 39 to 46 in the second long series, and 71 to 78 in the third. The transition metals under consideration here for use at elevated temperature are those of Groups IV, V and VI, and in order of increasing atomic weight Ti, V, Cr, Zr, Cb, Mo, Hf, Ta and W.

**Table I – Solid Solubilities of Various Carbides in Binders at 2300° F.**

| Carbide | Solubility (Weight %) for Cobalt | Nickel | Iron |
|---|---|---|---|
| Columbium, CbC | 5 | 3 | 1 |
| Chromium, $Cr_3C_2$ | 12 | 12 | 8 |
| Molybdenum, $Mo_2C$ | 13 | 8 | 5 |
| Tantalum, TaC | 3 | 5 | 0.5 |
| Titanium, TiC | 1 | 5 | 0.5 |
| TiC-WC (50:50) | 2 | 5 | 0.5 |
| Tungsten, WC | 22 | 12 | 7 |
| Vanadium, $V_4C_3$ | 6 | 7 | 3 |

data available to compare its physical properties with those of the more familiar two-phase cermets.

**Oxides** are still relatively unknown as bases for cermets. Oxides can hardly be metal-bonded because ternary reactions occur at service temperatures. Generally, it is also very difficult to control processing conditions. A great deal of more fundamental work will have to be done on this type of cermet.

### Mechanical Specifications

Here we run into the very practical problem of meeting the requirements of the customer – an engine manufacturer or some branch of the armed forces.

Early specifications called for oxidation resistance (weight gained in oxidizing media) at high temperature during 50 to 250 hr. at 1800 to 2000° F. It was eventually recognized that retention of original strength is more important than weight gain, and on this basis a number of cermets had to be rejected.

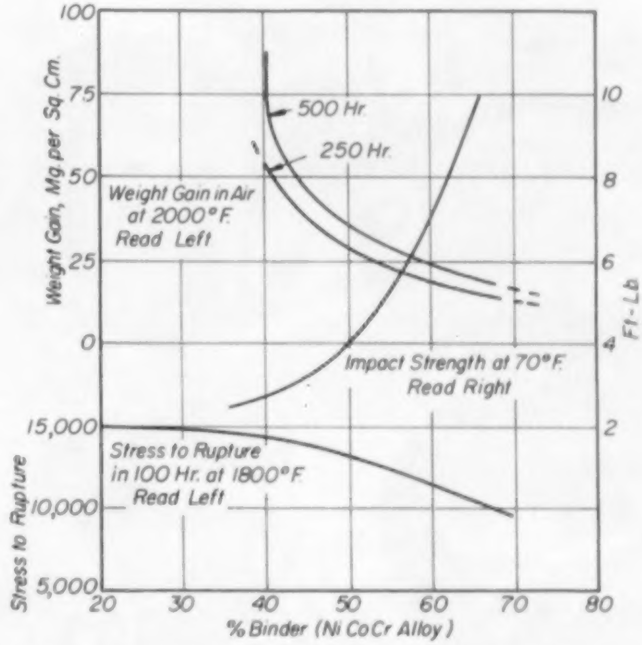



*Fig. 2 – Relationship Between Amount of NiCoCr Alloy Binder and the Stress-to-Rupture in 100 Hr. at 1800° F., the Weight Gain in Air at 2000° F., and the Room-Temperature Impact Strength of a Titanium Carbide Cermet.*

It was also found that the short-time transverse rupture strength (taken over from tungsten carbide technology) both at room and elevated temperatures could not evaluate new materials for services where resistance to creep under long-time stress was of much greater importance. Faulty specifications therefore confused and hampered this entire development. Strength requirements are now expressed in stress-to-rupture figures, and are much better for separating the good from the bad. The tests obviously evaluate the material both as to its high-temperature strength and its oxidation resistance.

Another important criterion is resistance to sudden changes in temperature, or heat shock. Both the Air Force and the National Advisory Committee for Aeronautics have devised cycling tests for a vane or disk sample. Unfortunately, thermal shock resistance depends greatly upon the shape of the piece. Therefore, we can hardly predict the performance of a given material from its basic properties, such as specific heat, thermal conductivity, modulus of elasticity or thermal expansion. Researchers must worry about the elimination of mechanical imperfections, porosity, metallurgical inhomogeneities and other stress-raisers which might cause premature failure of the sample without necessarily reflecting on its actual heat shock resistance. The testing apparatus is complex and the metals engineer can expose his sample to certain cycling tests only, leaving the actual evaluation to the prospective user, namely the Air Forces or the engine manufacturer.

The last but not the least criterion is impact strength. The engine designer maintains that cermets cannot be considered satisfactory for jet engines unless they resist "fragmentation". Obviously materials that are strong at elevated temperature and constant stress are resistant to creep and plastic deformation. By virtue of their structure and compared with conventional steels and superalloys, they must be considered "brittle", but I make so bold as to say that this is a fairly desirable characteristic if strength and "resistance to creep" are paramount, and completely contradicts the requirement for high impact resistance. If these two opposing properties must be met in a cermet type of material, a compromise must be sought. Attempts along these lines typify today's research.

Tentative standardization of an impact test eliminated a great number of materials. Consequently this progress report on cermets can con-

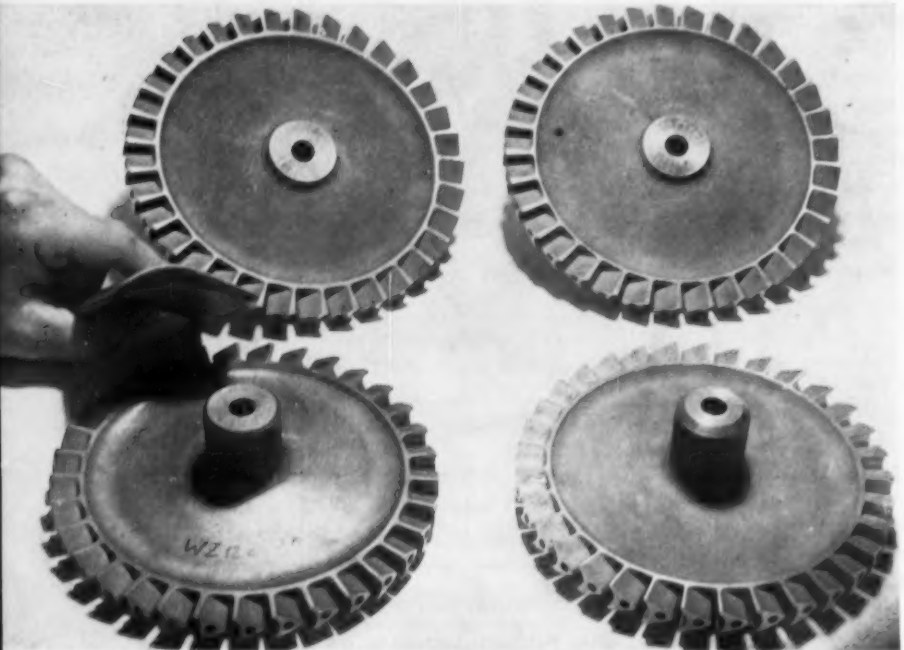


*Fig. 3 – Some Titanium Carbide Cermet Parts with 50% TiC, 50% NiCr*

tions are not without promise.

All cermets of the aluminide, titanium carbide and boride type are prepared by powder metallurgy methods. Since all compositions to be mentioned appear to be satisfactory from an oxidation, strength and heat shock point of view, their present status of development should be judged mainly on their impact strength.*

**Titanium carbides** are now produced by four or five American firms. Although their products vary somewhat in carbide composition and metal binder, this family of cermets can be described as a combination of carbide and alloy, usually of the metals Ni-Cr, Co-Cr, Ni-Cr-Co, Ni-Al, or Ni-Mo. The carbide proper may vary in its free and combined carbon, its TiO or TiN content, or the amount of either Cr or Mo in solid solution.

Two principal techniques have been employed to impart satisfactory oxidation resistance: (*a*) additions of chromium in solution with the binder or (*b*) CbC-TaC additions in solution with the TiC. Either will tend to produce phases which stabilize the protective oxide film consisting mainly of $TiO_2$.

These cermets based on TiC are principally a mixture of two phases – soft metal and hard carbide. A typical photomicrograph is Fig. 1. Metal additions may range from 20 to 70% by

fine itself to the most promising materials in three prominent groups – titanium carbide base, metal borides, and the aluminides.

**Cermets Now Available**

Had this paper been prepared two years ago, the molybdenum disilicide bodies would have been included, but poor heat shock resistance appears to have eliminated the majority of the silicides. About 18 months ago the chromium-alumina materials became less interesting because of the then current requirements for impact resistance. Unfortunately, it does not follow that the materials based on titanium carbide, the borides and the aluminides have met the impact specifications because it is primarily an indication that continued attempts to meet such specifica-

*Evaluation of cermets by impact testing created considerable confusion. Standard Charpy tests, designed for metals, gave poor indications as to the resistance to impact of cermet compositions; solid and apparently unnotched specimens yielded unreliable information by virtue of notches actually present and uncontrollable in these relatively brittle materials.

To overcome these difficulties in evaluating cermets, the N.A.C.A. developed a drop test designed to eliminate "toss energy", the kinetic energy transmitted by the impacting hammer to the fragments of the specimen. This new test apparatus, in which the specimen is gripped in a vise, makes use of a weight striking the cantilever-beam specimen near the free end. This weight is dropped from increasing heights until fracture occurs.

It is doubtful whether this N.A.C.A. equipment will become the standard for cermet impact testing. One of its major disadvantages is that it applies impact energies with relatively low velocities. It is expected that during actual service operations engine components may be loaded at velocities ranging between 500 and 900 ft. per sec. Ballistics tests are therefore being designed for cermet impact evaluation. Since ballistic evaluation is still incomplete, all impact data reported here will, unless stated otherwise, refer to results obtained using the N.A.C.A. type equipment.

weight and effect of variation in metal content on the physical properties is of special interest.

For example the modulus of elasticity is lowered with increasing binder content; also it decreases almost linearly with temperature—see Table II.

Oxidation resistance is greatly increased with increasing amounts of nickel-cobalt-chromium binder, as shown in Fig. 2, while the stress-to-rupture strengths decrease with the amount of metal. Up to about 50% by weight of metal added to TiC there is little change in this property (Fig. 2). This emphasizes the predominant influence of TiC on the strength characteristics of these cermets in this range of compositions; the carbide phase apparently prevents excessive creep.

Figure 2 also demonstrates the importance of metal additions beyond 50% for increased impact resistance, measured by Charpy test on standard square unnotched specimens, 10 × 10 mm. The sharply rising curve of impact is of importance since the stress-to-rupture strength is little affected as the metal percentage increases from 50 to 65%. There is undoubtedly room for further improvement of impact strength; the ultimate goal is 20 ft-lb., and the investigators of these materials appear quite hopeful of success within a relatively short time. In addition to composition changes, both in quantity and type, they pin their hopes on controlled microstructure and heat treatments. Spheroidization of the carbide particles appears to improve the impact strength. Certain infiltration techniques have produced samples with surfaces very rich in metal and subsequently with a greater tendency toward plastic deformation at the surface rather than crack propagation during impact testing.

Figure 3 shows some parts made of TiC-base cermets. Fabrication techniques have seen great progress during the last few years. There are still enormous manufacturing difficulties, and it is to be hoped that the engine designer will meet the materials engineer half way in a compromise on some design features.

At least half a dozen organizations concern themselves with studying and developing titanium-carbide-base materials. The sum of money invested in this research can hardly be accurately stated, but is somewhere in the neighborhood of $5,000,000.

**Metal borides,** in comparison, have received much less attention.

In discussing metal borides it should be kept in mind that the requirement for superior oxidation resistance has eliminated all but certain borides of zirconium, titanium and chromium,

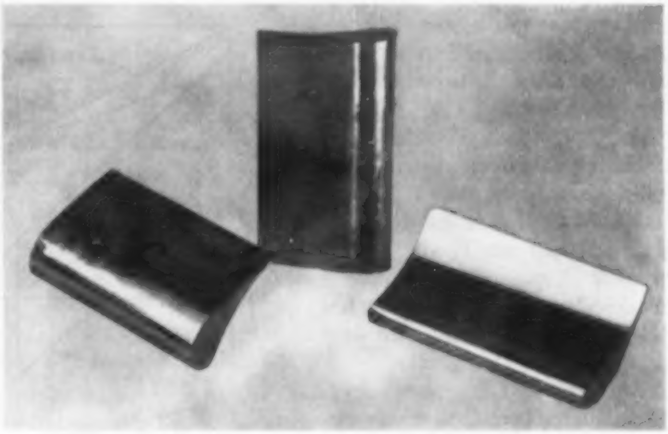
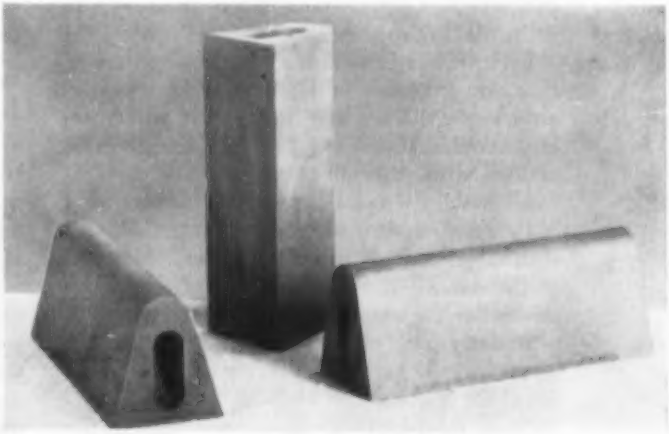


*Fig. 4 – Flame Holders Made of Chromium Boride*

**Table II – Effect of Binder on Modulus of Elasticity**

| Temperature | Binder | | |
|---|---|---|---|
| | 40% NiCoCr | 40% NiCr | 50% NiCoCr |
| Room | 56,250,000 | 54,250,000 | 51,000,000 |
| 800° F. | 52,500,000 | 51,000,000 | 47,000,000 |
| 1600° F. | 48,250,000 | 46,750,000 | 42,250,000 |

*Fig. 5 – Nickel Aluminide Nozzle Deflection Vanes*



and of these three, only the chromium-base borides appear to be able to replace the present metallic superalloys. The diboride phases of titanium and of zirconium have enough thermal stability, but both pure $ZrB_2$ and $TiB_2$ are far too brittle to be of any practical use. Having an extremely high melting point, a modified zirconium diboride has been very successfully used as a component in jet engines.

Metal borides are more refractory than the titanium carbide cermets. They do not depend for their strength on a metallic phase, such as a nickel-chromium alloy. The more outstanding compositions are substantially of chromium-molybdenum and boron. Their anticipated service temperatures will be between 1800 and 2100° F. In oxidation resistance and high-temperature strength (as shown in Fig. 6) they are quite superior to the titanium-carbide-base cermets, and are equal in terms of heat shock resistance. In resistance to impact, in the N.A.C.A. impact drop test, they are somewhat deficient, although even here they are not much worse than the TiC-base materials containing less than 40% by weight of binder metal as shown in Fig. 2. Some specific figures are:

Zirconium boride ("Borolite I") < 0.5 in-lb.
Chromium boride ("Borolite IV") 2 in-lb.
Bonded Cr boride ("Borolite V") 6 to 8 in-lb.

Here again, emphasis is being placed on improving the impact strength. Controlled microstructure and certain purification processes will be helpful in this respect.

Relatively little work has been done on manufacturing problems. In Fig. 4, some flame holders are shown, a chromium boride part which has given comparatively good performance in competition with other materials.

**Aluminides** – As far as the author knows, most of the research done to date has concerned itself with the zirconium, the titanium, and the nickel aluminides. Of the three, the nickel aluminides are by far the most interesting. However, since the matter has been studied for less than two years, it could hardly be said that the picture is anywhere near complete.

Of the three materials discussed – namely, the titanium-carbide-base cermets, the metal borides, and the aluminides – the latter appear to be the more ductile and impact resistant. N.A.C.A. drop test for the nickel aluminide tradenamed "Albis I" is 10 to 12 in-lb. Even this is far below a superalloy such as Haynes Alloy No. 31 or X-40, which developes 60 in-lb. in the same test. On the debit side, their high-temperature strength is also lowest, although probably sufficient for applications such as nozzle deflection vanes (Fig. 5). It can be expected that within the year significant tests may very well put the aluminides prominently in the foreground.

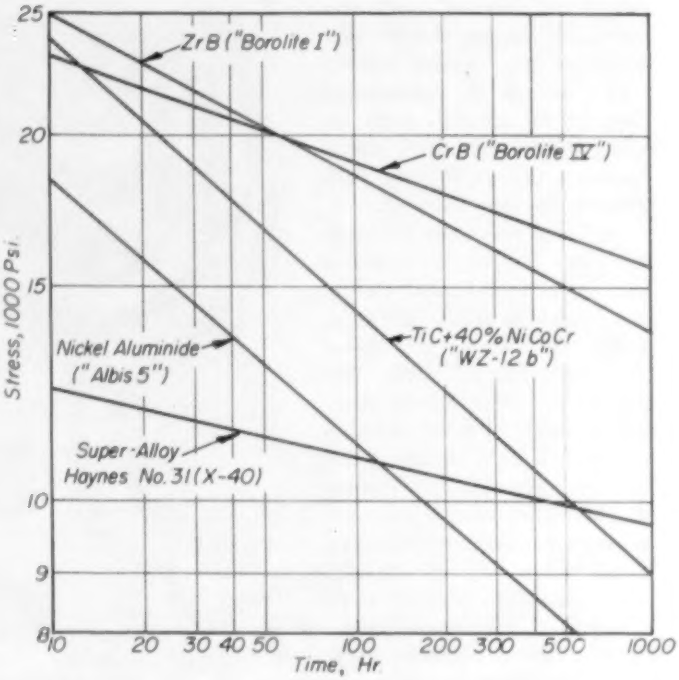



*Fig. 6 – Stress to Rupture at 1800° F., as It Varies With Time, for Various High-Temperature Materials*

**Summary**

In Fig. 6 stress-to-rupture strengths at 1800° F. of various cermets have been compared. It can be seen that these materials, "brittle" though they may be at room temperature, are far superior in load-carrying ability when hot even to such an excellent alloy as X-40.

Of the cermets available today, those based on titanium carbide are undoubtedly the best developed. They have gone beyond the testing stage and into production of fairly complicated shapes. Turbine wheels are now installed in experimental engines. *(Continued on p. 138)*

# A Universal Polishing Method

*By H. S. CANNON**

**A decade of experience with two grades of high-purity alumina polishing powder has resulted in standard procedures for a wide variety of materials, thus reducing many of the metallographer's cut-and-try methods to routine.**

PRIOR TO 1940, metallographic polishing was a complex art demanding extensive knowledge of many abrasives and appropriate manipulations and other techniques. Moreover, nonuniformity in particle size and cutting action of different lots of the same powder made it almost impossible to reduce metallographic polishing to a routine operation.

In 1943, Linde Air Products Co. marketed two grades of alumina abrasives,† which combined the characteristics judged most desirable in a polishing powder, namely, uniformity of particle size, fast cutting action, low cost, and easy use. The accumulated experience of the past ten years has revealed another asset – versatility – and they are now used exclusively by many large laboratories for all metallographic polishing. Materials with as widely divergent properties as lead, brass, steel, cast iron and cemented carbides can be polished with only slight modifications of a single basic technique.

Some understanding of the differences of the two powders is desirable. Both are high-purity forms of alumina (99.9+), and both resist attack by common acids. Other characteristics are:

| | ALPHA | GAMMA |
|---|---|---|
| Crystal system | Hexagonal | Cubic |
| Hardness, Mohs scale | 9 | 8 |
| Approximate particle size | 0.3 micron | 0.03 micron |
| Apparent density, dry, g. per cc. | 0.3 to 0.6 | 0.2 to 0.5 |

As shown by electron micrographs, Fig. 1, the particle size of both powders is very uniform although the gamma alumina is much finer than the alpha. It is this difference in particle size, along with the difference in hardness, which gives the powders their individual properties. Alpha alumina is a fast-cutting powder, which produces a clear, unsmeared metal surface of fine finish. Gamma is somewhat slower in cutting action but produces a finer finish suitable for photographing at 1000 × or higher. Alpha is usually used for initial cloth wheel polishing, and gamma if a very fine finish is required. In the preparation of specimens for routine examination, polishing with the coarser alpha powder is usually sufficient.

**Basic Polishing Technique**

The procedure listed step by step below is illustrated with photomicrographs of a medium carbon steel, Fig. 2.

1. Cut off a portion of the material to be examined, keeping the area to be polished below 1 sq.cm. if possible. If the surface is very rough, smooth with a file, and if the piece is too small to hold conventionally, mount it in a plastic material such as Bakelite molding resin BM 7639.

2. Grind successively on No. 2, 1, 0, 2/0, and 3/0 metallographic paper, taking care to rotate the sample 90° with each change of paper so that all scratches from the preceding paper are removed. The specimen at 100 × should look like the left micro in Fig. 2.

2a (Optional). If inclusions or soft phases in a harder matrix are to be retained, grind further

*Tonawanda Laboratory, Linde Air Products Co., Tonawanda, N.Y.

†Designated commercially as Linde A (alpha alumina) and Linde B (gamma alumina) and also sold by several laboratory supply houses under their own labels.

on a well-worn, graphite-coated 3/0 paper or grind wet on worn 600-mesh abrasive paper.

3. The specimen is now ready for wet polishing on a cloth-covered wheel. A medium or short-nap cloth such as woolen broadcloth, billiard cloth, or double thickness of "Flightex Fabric" should be wet with water and stretched taut on a metallographic polishing wheel. Alpha alumina can be applied to the cloth either as a dry powder (worked into the cloth with the fingers) or poured on as a water suspension. With the wheel rotating at 600 to 1200 rpm., hold the specimen firmly against the wheel and rotate slowly in a direction counter to that of the wheel

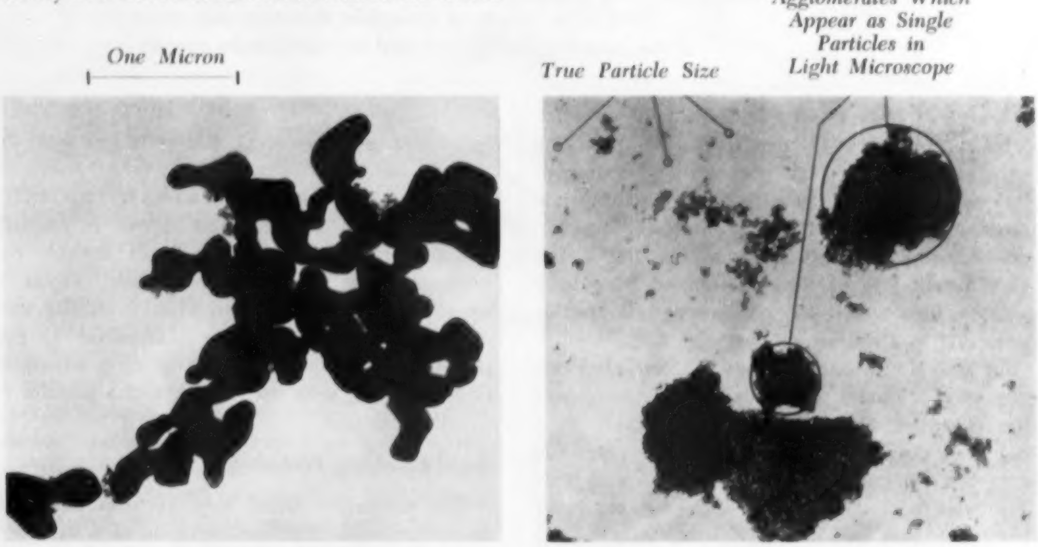



*Fig. 1 – Electron Micrographs Show Difference in Particle Size of Alpha Alumina (Left) and Gamma Alumina (Right), and Also Uniformity of Particle Size. 25,000 ×*

(to prevent formation of "comet tails" arising from directional polishing). To make full use of the fast cutting action of this abrasive, the cloth must not be saturated with water. The correct degree of moisture can be judged by lifting the specimen from the wheel – the film of moisture on the specimen's surface should evaporate in 2 to 5 sec. Ordinarily, 1 to 2 min. polishing should be sufficient to remove the coarse scratches left by abrasive papers and give a surface such as photographed in the second micro in Fig. 2.

4. If the specimen is to be examined only at low magnifications, Step 3 can be finished by moving the specimen to a position 1 or 2 in. from the center of the same wheel (where the linear speed is lower) and reducing the pressure. Polishing for 30 sec. will usually produce a clear, relatively scratch-free surface for magnifications less than 500 ×.

5. For higher magnifications, wash the specimen thoroughly and polish on a second wheel covered with a soft cloth such as silk velvet, "Microcloth" or "Val-Chamee", using the gamma powder. One to two minutes will usually remove all scratches, leaving a surface at 1000 × such as shown in the micro at right in Fig. 2.

6 (Optional). Some metals, especially the softer ones, may develop a distorted flowed surface. While both powders minimize this effect, it is sometimes necessary to etch and polish alternately several times to reveal the true structure. The etching should be as light or lighter than the contemplated final etch and only light pressure should be used on the polishing wheel. Three cycles are usually sufficient.

## Modifications for Various Materials

**Soft Metals Such as Aluminum and Lead** – In Step 2 of the above "standard" procedure, use a solution of paraffin in kerosene (50 g. per l.) to prevent clogging of the papers with soft metal particles. Clean the specimen thoroughly with a solvent between papers.

In Step 3, polish the specimen initially in the direction of the scratches to prevent filling them up with flowed metal. If a hard cloth such as

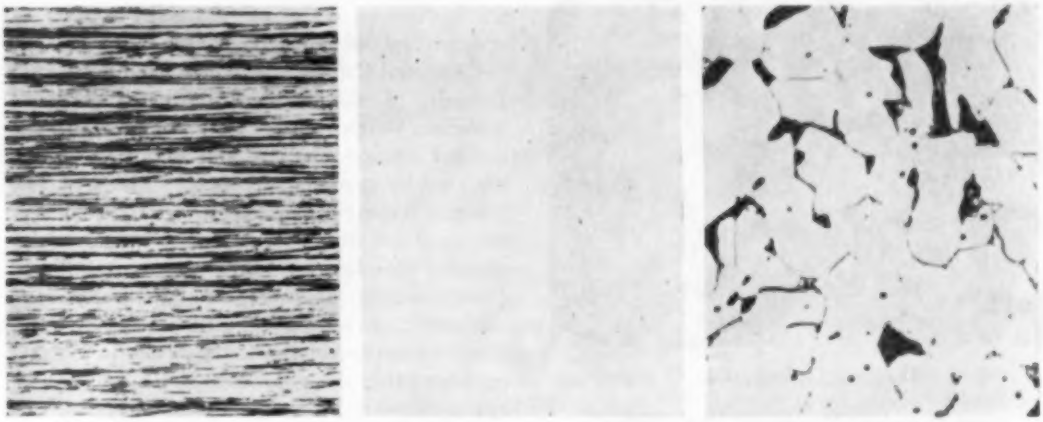


*Fig. 2 – Micrographs of Medium-Carbon Steel Illustrate Basic Polishing Procedure. Left shows at 100 × coarse scratches left by grinding on 3/0 paper (Step 2 in text). Center shows surface polished 1 min. with alpha alumina at 100 × (3 in text). Right has finally been polished 1 min. with gamma alumina and etched with nital (Step 5 in text). 1000 ×*

"Flightex Fabric" is used, it should be backed up with a more resilient material such as billiard cloth. When the initial scratches have been removed, use the circular polishing technique. A slower wheel, 150 to 250 rpm. instead of 600 rpm., is often preferred for soft metals.

In Step 5, work a liberal amount of mild soap into the cloth in addition to the gamma alumina. Distilled water often gives better results than tap water. The specimen should be polished for only 30 to 90 sec. at light pressure. Figure 3 shows a specimen of 3 S aluminum polished by this technique.

**Copper and Copper Alloys** – Use the standard procedure as outlined above, without change.

**Stainless Steels** – Follow standard procedure except that in the final stages of polishing, the pressure exerted on the specimen is gradually relieved.

**Cast Iron and Specimens Containing Inclusions** – In Step 2, worn abrasive paper is preferable to new paper. Step 2a should be used.

Since both graphite and inclusions tend to be pulled out by the fibers of the polishing cloth, napless materials must be used for wet polishing. Therefore, for Step 3, "Flightex Fabric" is preferred and for step 5 use "Microcloth" or a silk cloth on a high-speed wheel (1200 rpm.). Rotat-

*Fig. 3 – Aluminum Alloy 3 S Polished by Modification of Technique for Soft Metals. Lightly etched with 0.5% HF. 500 ×*

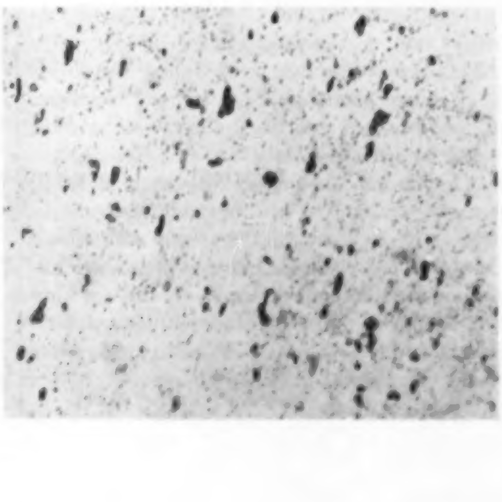


*Fig. 4 – Nodular Cast Iron; Procedure Modified to Prevent Dislodgment of Graphite. Unetched. 1000 ×*

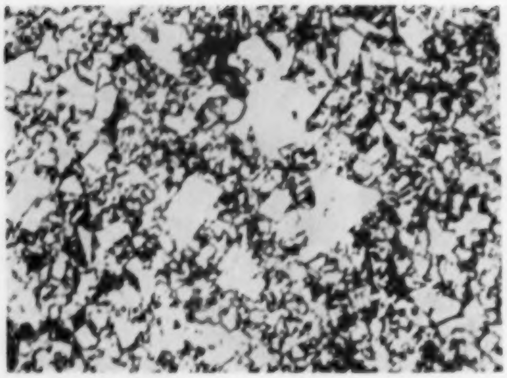


*Fig. 5 – Tungsten Carbide With 6% Cobalt Binder Polished by Modified Procedure for Hard Materials. Murakami's etch. 1500 ×*

ing the specimen during polishing also increases the chance of graphite dislodgment, so this technique should be disregarded in both Steps 3 and 5. The wheel should be kept only slightly moist. With cast iron, somewhat longer polishing times are required but the specimen should be checked periodically at 100 × to make sure it is polished no longer than necessary. As soon as the scratches from the abrasive paper are removed, the specimen should be transferred to the high-speed wheel using gamma powder. A nodular cast iron is shown in Fig. 4.

**Cemented Carbides and Hard Facing Alloys –** Because of the extreme hardness of these materials, rough grinding is best done with resin-bonded diamond wheels, and step 2 should be replaced by grinding successively with 100, 200, 350 and 500-mesh diamond wheels. Then polish the specimen firmly for 3 to 5 min. with alpha alumina plus kerosene on a paper-covered lap. (Single-weight photographic paper, emulsion side down, is excellent.) Finish-polish for 3 to 8 min. on a napless cloth such as "Flightex Fabric" or "Metcloth", using gamma alumina plus water as the abrasive. A cemented carbide specimen so prepared is shown in Fig. 5.

The techniques described will serve for most of the specimens a metallographer may have to polish. Metals not referred to specifically should be polished according to the procedure described for similar metals – for example, magnesium as for aluminum. Slight modifications may be necessary in some instances but, in general, any metal specimen can be polished with standard equipment using alpha and gamma alumina and following these simple procedures.

## Nominating Committee for A. S. M. National Officers

In accordance with the constitution of the American Society for Metals, President George A. Roberts has selected a nominating committee for the nomination of president (for one year), vice-president (for one year), treasurer (for two years), and two trustees (for two years each). This committee was selected by President Roberts from the list of candidates submitted by the chapters. The personnel of the nominating committee is:

Max W. Lightner (Pittsburgh Chapter), United States Steel Corp., 525 Wm. Penn Place, Pittsburgh 30, Pa., *Chairman*.

William L. Badger (Boston Chapter), General Electric Co., 920 Western Ave., West Lynn, Mass.

Hiram Brown (Des Moines Chapter), Solar Aircraft Corp., Des Moines, Iowa.

Mathew A. Hunter (Eastern New York Chapter), Rensselaer Polytechnic Institute, Troy, N. Y.

Commander H. J. Huester (Jacksonville Chapter), Naval Air Station, Jacksonville, Fla.

W. J. Nash, Jr. (Los Angeles Chapter), C. F. Braun & Co., 1000 S. Fremont Ave., Alhambra, Calif.

George Parkins (Louisville Chapter), Reynolds Metals Co., 2500 South Third St., Louisville 1, Ky.

A. J. Scheid, Jr. (Calumet Chapter), Columbia Tool Steel Co., Lincoln Highway and State St., Chicago Heights, Ill.

Don Sener (York Chapter), Harrisburg Steel Corp., Harrisburg, Pa.

This committee will meet during the third full week in the month of May. It will welcome suggestions for candidates in accordance with the Constitution, Article IX, Section 1 (b), which provides that endorsements of a local executive committee shall be confined to members of its local chapter, but any individual member of a chapter may suggest to the nominating committee any candidates he would like to have in office. Endorsements may be sent in writing to either the chairman or any member of the committee.

# Large Molybdenum Ingots by Arc Casting

*By NORMAN L. DEUBLE**

**First of a series of articles on arc-cast molybdenum and molybdenum-base alloys describes the manufacture of high-purity molybdenum powder, its continuous formation into a consumable electrode, and its arc melting in a high vacuum into half-ton ingots of theoretical density.**

TEN YEARS AGO, metallic molybdenum was used principally for relatively small parts in the electric and electronic industries. This is understandable in view of the fact that molybdenum at that time was produced only by powder metallurgy. It was an accepted belief that pure molybdenum could not be satisfactorily melted without contamination, primarily because of the lack of suitable crucibles, either metallic or nonmetallic. Other difficulties were the high melting point and rapid oxidation of the metal. Despite these formidable obstacles, Climax Molybdenum Co. started working on the idea that forgeable molybdenum ingots could be produced by vacuum-arc melting in a water-cooled copper mold.

Details of the successful fulfillment of this idea were first published in 1946 by R. M. Parke and J. L. Ham ("The Melting of Molybdenum in the Vacuum Arc", *Transactions,* American Institute of Mining and Metallurgical Engineers, Vol. 171, 1947, p. 416 to 430). This development was among the first, if not the very first, of the "consumable electrode" equipment which has proved so valuable in melting rare and reactive metals coming into engineering importance. The electrode is molded of powder, compacted and sintered continuously, and as it slowly emerges its lower end is melted into a water-cooled mold. All this in a high vacuum.

Developments since 1946 have confirmed the soundness of the original concept and arc-cast molybdenum has become an engineering material for military and civilian high-temperature applications. The metal and its alloys have outstanding inherent characteristics – high modulus of elasticity (47,000,000 psi.), very low coefficient of expansion, and high thermal conductivity – that make them exceedingly attractive in many fields, sometimes the only feasible material for a particular part. Climax Molybdenum Co. has formulated alloys with elevated-temperature strengths far superior to that of any existing metallic material. These alloys can be rolled, forged, extruded and processed by conventional practices. Available sizes and quantities of arc-cast molybdenum are limited only by present melting facilities, which can be readily enlarged if necessary. The older specialized uses in electronics will recede into relatively minor tonnage when molybdenum's full possibilities for structural and mechanical uses at high temperature are realized.

**Powder-Metallurgy Process** – In the conventional powder-metallurgy method, molybdenum powder is compacted into ingots or bars which are then sintered by resistance heating in a hydrogen atmosphere at about 4000° F. (Larger ingots must be heated by radiation.) Minimum density of pressed ingots is 8.5 g. per cc. and of sintered ingots 9 g. per cc.; after sufficient mechanical working, the density approaches the theoretical 10.22 g. per cc.

Commercial powder-metallurgy ingots are generally 1 × 1 × 14 in. (about 7 lb.) or 1 × 2 × 14 in. (about 14 lb.) These are large enough for most electrical and electronic requirements. One company, however, can produce sizes up to 36 sq. in. in cross section and 500 lb. in weight by this method.

* Manager, Metallic Molybdenum Sales, Climax Molybdenum Co., New York City.

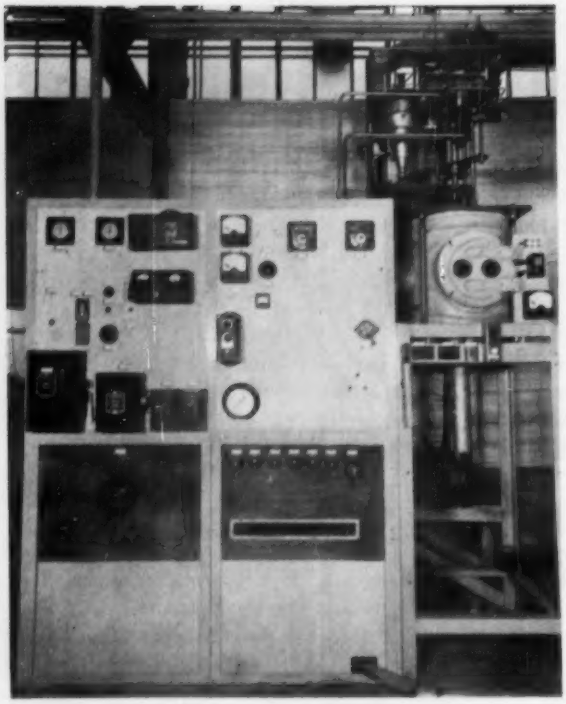


*Fig. 1 – PSM 3 Furnace at Right of Control Panels. Molybdenum ingots up to 6 in. diameter and 30 in. long weighing approximately 250 lb. can be arc-cast in this unit*

**Arc-Casting Process** – After the feasibility of the vacuum-arc melting of molybdenum had been proved on a small scale, a larger furnace incorporating continuous pressing, sintering and melting was constructed. This furnace, designated as PSM 3 (pressing-sintering-melting No. 3 design), is shown in Fig. 1 at the right of the control panels. The electrode is formed from molybdenum powder, which has been previously mixed by tumbling in a ceramic-lined barrel with a small amount of carbon. While carbon is the usual deoxidant, other materials have been used on an experimental basis. Up to 30% of chips prepared by crushing arc-cast molybdenum turnings can be included when available. Alloying elements may also be mixed into the charge.

This charge is fed from the hopper shown in the background above the furnace by a vibrating plate to the mechanically operated compacting mechanism, wherein successive segments of the electrode are formed in a split cylindrical die so designed that the radial pressure is released at a predetermined vertical compacting pressure. Pressure must be such that the compact will have sufficient green strength so it will not crumble. The electrode must then be

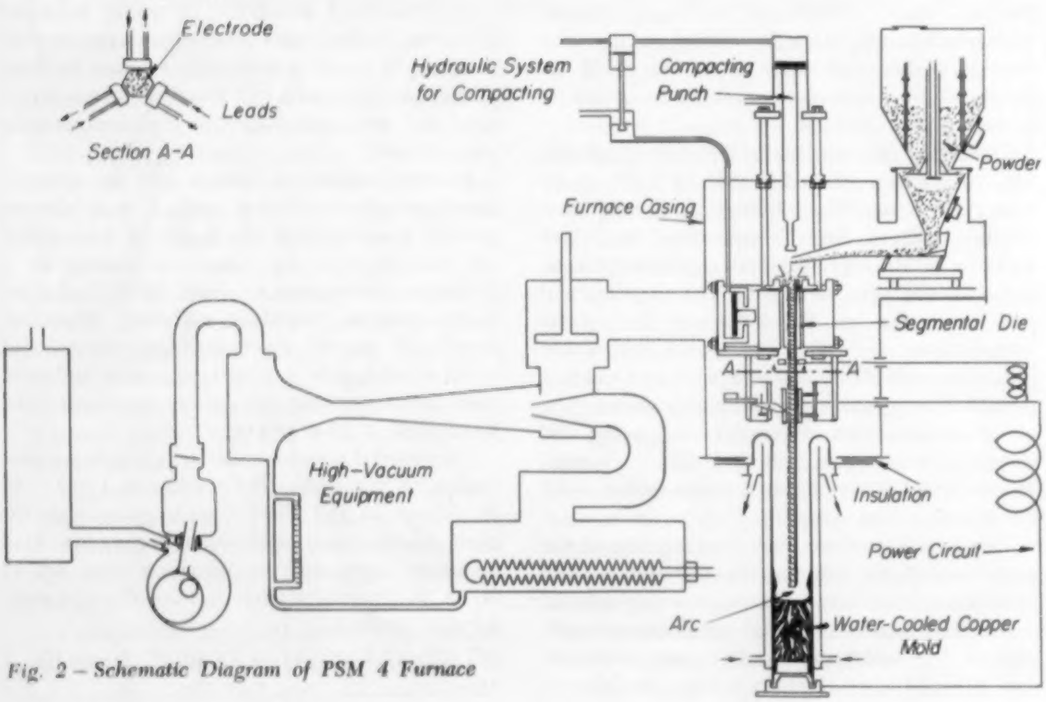



*Fig. 2 – Schematic Diagram of PSM 4 Furnace*

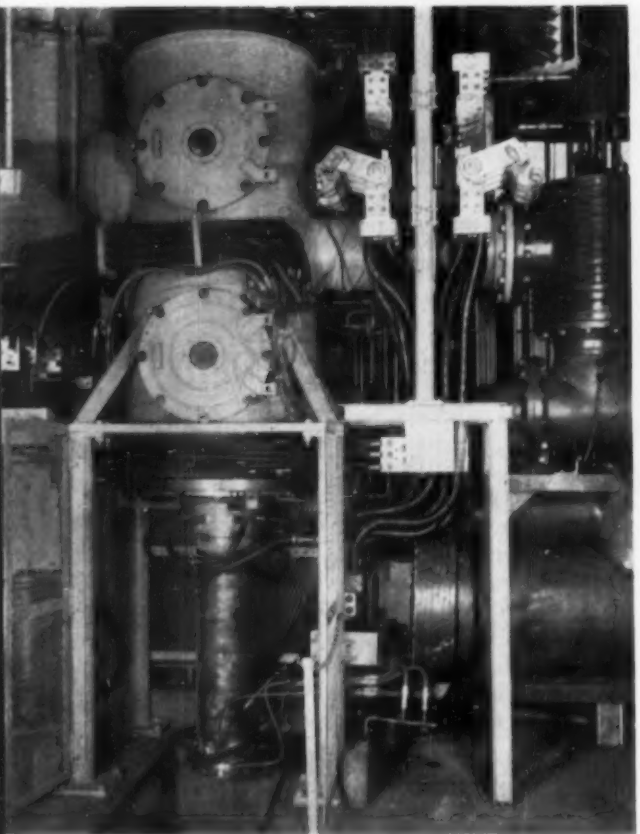


*Fig. 3 – PSM 4 Furnace Ready for Operation; Cage Door Open to Show Mold. Powder feed for electrode at upper left; vacuum equipment at right*

sintered so it can support its own weight when it reaches to the bottom of the mold. One contact of the sintering circuit is the die; the other is a pair of water-cooled copper shoes approximately 10 in. below. Obviously, the sintered electrode must be straight and centered to avoid contact with the side of the mold.

The a-c. arc current flows from the water-cooled copper shoes through the electrode to the arc gap (where melting occurs), thence to the bath and ingot, and finally to a water-cooled plate forming the bottom of the mold. The mold is water-cooled and attached to but insulated from the bottom of the furnace shell or enclosure. The entire operation of pressing, sintering and melting has to be carried out in a nonoxidizing environment – normally a vacuum.

In spite of all the difficulties involved in obtaining a satisfactory vacuum, making a suitable electrode, and coordinating electrode feed with melting rate, the furnace proved highly successful and is being used to melt molybdenum ingots weighing as much as 300 lb.

**PSM 4** – Based on this experience a larger unit, PSM 4, was designed, and completed in 1950 (Fig. 2 and 3). In the PSM 4, the compacting mechanism was changed from a mechanical to a hydraulic system. Also, the electrode shape was changed from round to hexagonal, and the sintering circuits were arranged to heat three alternate sides of the electrode by resistance, with each circuit separately controlled. This procedure insured uniform sintering and a straight electrode.

Special techniques were developed to find and correct leaks so the unit can be evacuated to approximately 2 microns. During operation, however, the pressure usually rises to about 18 microns from the liberation of gas absorbed on the powder, and carbon monoxide from the deoxidizing reaction.

With the present power supply, molybdenum

*Fig. 4 – At Right, the Mold Into Which Molybdenum Is Arc-Cast, and at Left, Cast Molybdenum Ingot; Between Are Turned Sections Prepared for Extrusion*

ingots up to 9 in. diameter, 4 ft. long, and weighing 1000 lb. have been melted (Fig. 4). If a larger power source were available, ingots weighing up to a ton could be produced, and if the demand warranted, there is reason to believe that the furnace could be enlarged to produce an ingot possibly 18 in. diameter and 5 ft. long.

**Production of Powder** – Among the many problems that had to be solved was the manufacture of a satisfactory molybdenum powder. The usual commercial procedure is as follows:

1. Molybdenite concentrate ($MoS_2$) is roasted to "technical molybdic oxide" ($MoO_3$) in a Nichols-Herreshoff type of furnace common to the western smelters.

2. The technical molybdic oxide is sublimed in a Globar-heated rotary-hearth furnace at about 1900° F. Air sweeps the vaporized oxide to a bag filter where the "pure" oxide is collected. The very fine, fluffy sublimed oxide is densified before packing.

3. Producers of molybdenum powder further purify the oxide by dissolving it in ammonia, filtering and recrystallizing, repeating the procedure if necessary. Some producers then heat the ammonium molybdate crystals to produce molybdic oxide. The densified pure oxide or ammonium molybdate is given a preliminary hydrogen reduction in a tube furnace at about 1300° F. to produce "blue oxide" ($MoO_2$). After grinding and screening, the blue oxide powder is reduced in hydrogen at about 2000° F. to molybdenum powder, which is again ground and screened before final processing.

Commercial molybdenum powder suitable for powder metallurgical processes was, of course, first tried in the development of the arc-casting process, but slight differences in powder characteristics resulting from minor processing variables built up into major differences in melting. None was completely satisfactory. The two main disadvantages were fineness and high oxygen content. The finer powders could not be properly compacted to give adequate green strength; in addition, they oxidized and absorbed moisture while in storage and during handling.

**Table I – Vacuum-Fusion Analyses of Molybdenum**

| | Arc-Cast | Powder-Metallurgy |
|---|---|---|
| Oxygen | 0.0002 to 0.0022% (0.0007 av.) | 0.0005 to 0.0071% |
| Nitrogen | <0.0001 to 0.0002 (0.00011 av.) | 0.0001 to 0.004 |
| Hydrogen | 0.0001 to 0.0002 | 0.0001 to 0.0003 |

For a period, an experimental powder that had been given a special final hydrogen reduction was used with satisfaction but because of its cost, another effort was made to use a commercial powder. One of them had been found to be as good as the special powder except for its lower arc-carrying ability. This commercial powder was finally adapted for use by small additions of arc-stabilizing compounds. For arc-casting purposes final grinding and screening should be eliminated to avoid pick-up of undesired moisture and oxygen.

At the present time, molybdenum powder produced by hydrogen reduction of ammonium molybdate is purchased for arc casting. Samples of each lot are examined microscopically for particle size and structure. In addition the powder must meet two specific requirements: *(a)* 0.04% maximum weight loss on heating in dry hydrogen for 30 min. at 1950° F., and *(b)* 4500 psi. minimum compressive strength as determined on a pellet 1 in. diameter by 1 in. high compacted under a load of 12,000 psi.

Research to improve the quality of the powder, particularly in regard to weight loss and microstructure, is continuing.

## Advantages of Arc-Cast Molybdenum

Only arc casting will give *large* sections of molybdenum which can be fabricated into engineering parts by commercial methods. The three major advantages of arc-cast molybdenum stem directly from the melting process – larger sizes, higher density, lower gas content. Superior welding and machining properties are related to the last two factors.

Ingots of arc-cast molybdenum do not depend on mechanical working to reach theoretical density. For example, a 9-in. ingot produced some time ago had practically theoretical density as-cast. This insures sound metal throughout large cross sections, one of the advantages over powder-metallurgy molybdenum.

Arc-cast molybdenum is exceptionally low in gas content – particularly oxygen, which is believed to reduce ductility. Other impurities are about the same as in powder-metallurgy molybdenum; spectrographic analyses indicate values in the second and third decimal places. A comparison of various lots by one laboratory is shown in Table I.

The low and uniform gas content is one reason why one large manufacturer prefers arc-cast molybdenum for certain parts of its electronic equipment.

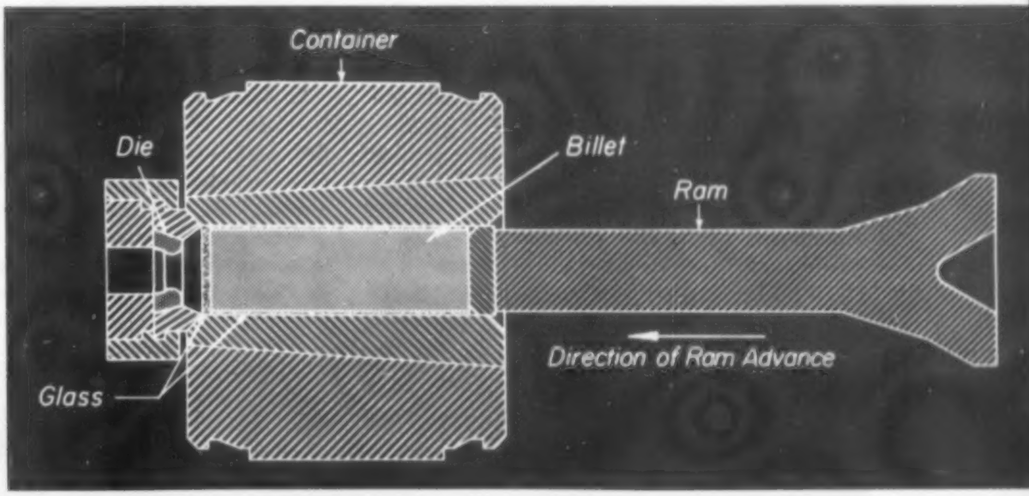



*Fig. 1 – Method of Coating Billet With Glass for Extrusion of Solid Shapes by the Ugine-Séjournet Process*

# Considerations for Selecting Steel Extrusions

*By S. O. EVANS**

**"Special" shapes, both in conventional and new alloys, are available to the designer at a significant economy when made by the hot extrusion process.**

Considerable interest has been created by the Ugine-Séjournet method of extruding steel that involves the use of molten glass as a lubricant. The method has increased the length of billets and the ratio of area reduction (called extrusion ratio) available in steel and high-temperature alloys. This greatly enhances the value of extrusion to the designer. Except for the glass lubricant, the process is like conventional extrusion in that a hot billet is placed in a container between a die and a ram. The ram advances and pushes the metal through the die and the emerging metal takes the form of the opening in the die. Hollow or tubular extrusions are made by drilling or piercing the billet, and a mandrel, attached to the ram, passes through

*Manager of Tubing Operations, Babcock & Wilcox Co., Beaver Falls, Pa.

this hole and through the die. Because the only escape for the metal is through the gap between mandrel and die, the emerging metal will have an outside shape similar to the die opening and an inside shape similar to the mandrel contour.

Lubrication is required on each surface where the hot metal slides over the tools of the extrusion press. In solid extrusion this is done by coating the billet with glass and inserting a cartridge of glass in front of the die as shown in Fig. 1. To produce a tube the same lubrication This cartridge melts progressively during the extrusion stroke, supplying a continuing flow of lubricant to the die.

In June 1950 the Tubular Products Div. of Babcock & Wilcox Co. obtained a license to use this Ugine-Séjournet process, installed appropriate equipment in 1951, and has been in production since early 1952. The mechanical aspects of tube production as practiced here involve the following steps: (*a*) piercing a solid billet to provide a concentric hollow to be fed to the

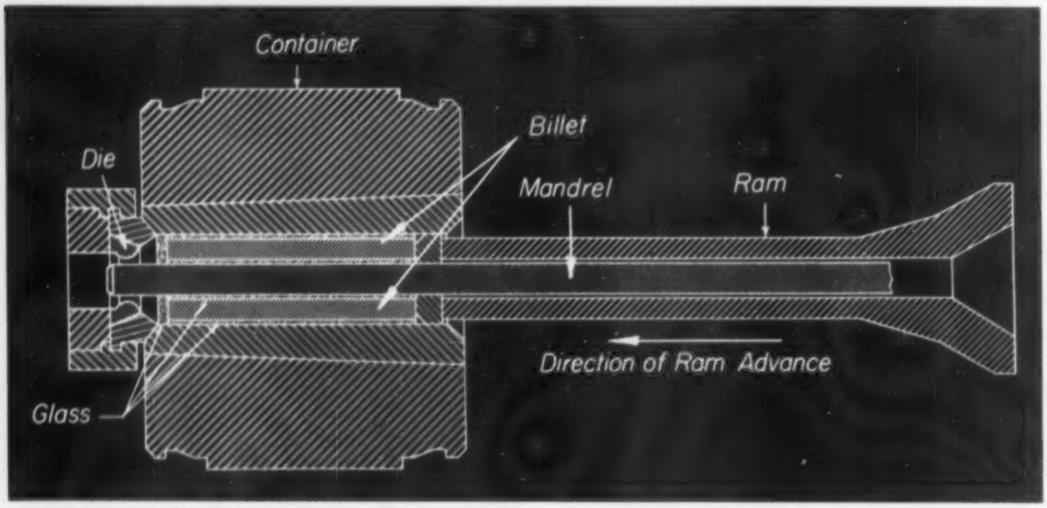



*Fig. 2 — Glass Lubricated Surfaces for Extrusion of Tubes*

is required plus a coating of glass inside the billet for lubrication between billet and mandrel, as shown in Fig. 2.

The uniform coatings of glass inside and outside are applied to the billet as it rolls toward the press. As the billet lies in a horizontal trough, a long spoon containing just enough glass to coat the inside of the hole is inserted and turned over, dropping a mound along the full length of the billet. Immediately the billet is kicked out of the trough and starts rolling down a ramp causing the glass to tumble along the bottom of the bore and thus distribute itself uniformly as it adheres to the hot billet. During this same travel the billet rolls over a bed of powdered glass, which has been raked smooth, for coating of the hot outer surface. In this way the billet arriving at the extrusion press is coated outside and inside with a uniform layer of molten glass. The die lubrication has previously been provided by inserting a cartridge of glass in the container. extrusion press; (*b*) extruding this hollow with a mandrel inserted in the hole so that the metal is forced out through the aperture between the mandrel and die.

Piercing is accomplished by heating the billet, applying powdered glass which softens to form a lubricant, and forcing a mandrel down through it in a vertical 500-ton press. The resulting hollow billet is reheated, relubricated and inserted in the container of a 2500-ton horizontal press for extrusion into a tube. The tube emerging from the press is covered by a minute layer of glass which must be removed before subsequent cold working. This is done quite easily either in a caustic-type pickle, used at elevated temperatures, or in a hydrofluoric acid pickle.

The value of extrusion to the designer falls in one of the following categories:

1. Permitting the use of new alloys that are difficult or impossible to work by previous methods.

2. Providing specially shaped tubes with outside and inside shapes that are not necessarily similar, such as a tube with round outside and shaped inside or one that is shaped outside and round inside.

3. Providing solid shapes that are difficult or impossible to obtain by rolling.

Obviously, if extrusion can now offer alloys that are difficult to work by previous methods and can produce hollow and solid shapes that are not otherwise obtainable, the designer can better solve his problems.

**Working New Alloys** – The difficulty or impossibility of hot working a metal is a matter of degree, with troubles caused by conventional working methods ranging from superficial cracks, which must be ground out, to the complete break-up of material. Extrusion has proved of value throughout this range.

The major portion of our early effort at Babcock and Wilcox was directed to the production of stainless steel tubing of the austenitic grades. These alloys are difficult to work because tubes produced by conventional rotary piercing require a considerable amount of grinding inside and out before subsequent cold work. Extruded tubes required almost none of the costly internal grinding, and need for external grinding was greatly minimized.

More spectacular than this has been the production of tubes in alloys that were previously considered "unpierceable" by conventional methods. Studies of extruding these difficult-to-work alloys are going on continuously. Several alloys which have been extruded with sufficient success that they are now offered commercially in the form of tubes are 19-9 DL, 440-C (see footnote for compositions) and pure titanium. In addition we have extruded solid bars in considerable quantity of pure and alloyed molybdenum, as well as smaller quantities of pure and alloyed zirconium and titanium. A partial list of the ferrous alloys that have been successfully extruded are: A-286, 16-25-6, 16-13-3 Cb, 25-12, 25-20 Cb (see footnote for compositions) and several of the tungsten and vanadium-bearing high-temperature toolsteels.

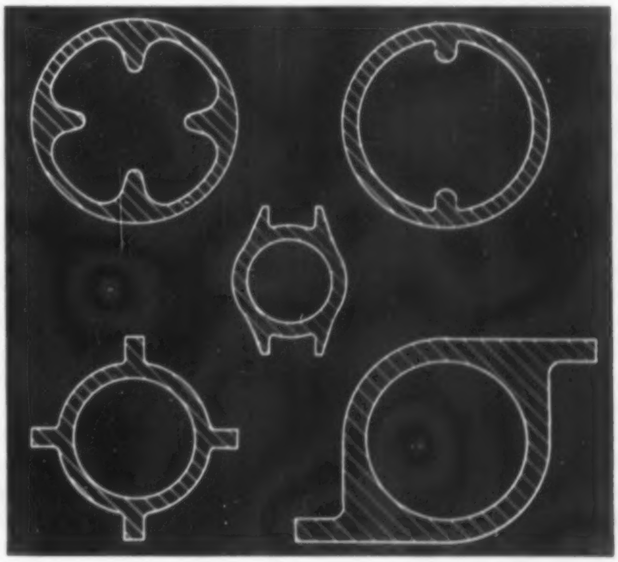
The method of heating the billets is often important in the extrusion of special metals and alloys. High-head gas-fired furnaces, induction furnaces (with atmosphere protection) and salt baths are all available and have been used successfully to heat metal for extrusion at the Babcock & Wilcox Co.

**Special Shaped Tubes** -- An odd shaped tube with nonuniform walls may be of advantage either for heat transfer or mechanical purposes. Figure 3 shows some of the shapes made in France by our licensor, some of which we have made here as well. Four of these shapes are designed for heat transfer between differing materials where either inside or outside extended surfaces are necessary. The center item is of stainless steel that has been produced in the extruded and cold drawn condition in France for wristwatch cases.

Another type of tube to which extrusion is particularly well adapted is the very heavy-walled kind which is difficult to produce by rotary piercing. Figure 4 shows four of the unusual tubes produced by Babcock and Wilcox, including a relatively heavy-walled tube, an

Compositions: 19-9 DL – 19.25 Cr, 9 Ni, 1.25 Mo, 1.25 W, 0.3 Ti, 0.4 Cb, 0.3 C; 440-C – 16 to 18 Cr, 0.95 to 1.20 C, 1.00 Si; A-286 – 25 Ni, 14.75 Cr, 1.9 Ti, 1.25 Mo, 0.2 Al, 0.25 V, 0.08 C; 16-25-6 – 25 Ni, 16.5 Cr, 6.25 Mo, 0.15 N, 0.10 C; 16-13-3 Cb – 16 to 18 Cr, 11 to 14 Ni, 2 to 3 Mo, 7.5 Si (Type 316) plus Cb 9 × C to 1% max.; 25-12 – 22 to 26 Cr, 12 to 15 Ni, 0.35 max. C, 2.0 max. Mn, 1.0 max. Si; 25-20 Cb – 22 to 26 Cr, 19 to 22 Ni, 2 max. Mn, 1.0 max. Si, 0.08 max. C, Cb 9 × C to 1% max.

*Fig. 3 – Shapes Produced in France by the Method of Using Glass as Lubricant During Extrusion*

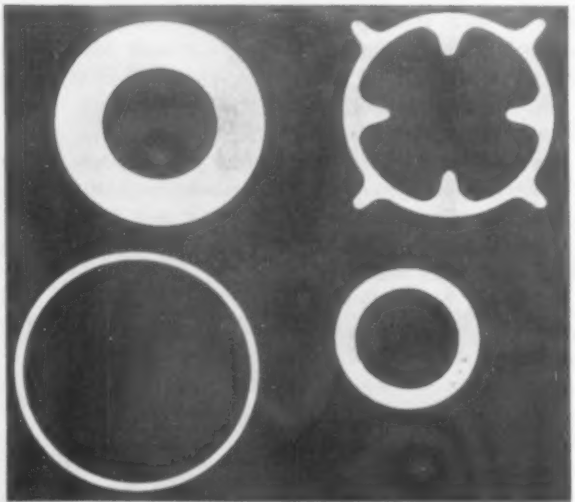


inside-and-outside-fin tube, a tube of pure titanium (lower left), and one of nodular iron (lower right).

**Solid Shapes** – The value of extruded solid shapes comes from the three following considerations:

1. Provision of shapes which cannot conveniently be rolled.
2. Provision of shapes not offered as standard mass-produced sections.
3. Provision of shapes in small unit quantities.

The shapes which cannot be rolled or are not offered may be in this category because excessive draft on some section may make the rolling impractical, or it may be for as simple a reason as that the shape is not offered in the grade of steel desired. Angles with one leg heavier than the other or simple shapes that are just far enough off the beaten path so that demand has never been sufficient to justify the commercial manufacture of rolls for these special shapes frequently force the designer to ask for expensive machining to fit his need. Many of these shapes may be produced by extrusion. Some examples of shapes we have produced are shown in Fig. 5.



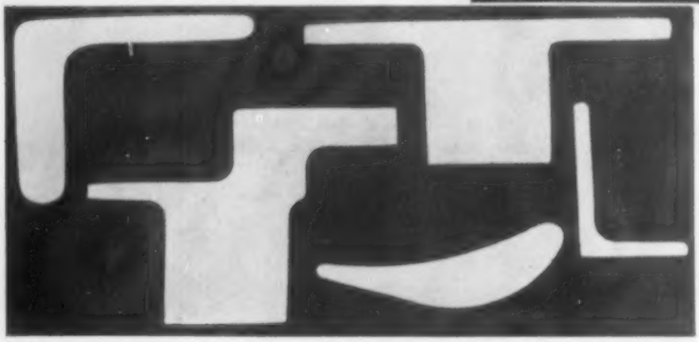


*Fig. 4 and 5 – Solid and Tubular Shapes Produced by Babcock & Wilcox Co. Using the Ugine-Séjournet Process*

When relatively small quantities of a new shape are desired, extrusion may well provide an economical source, even when rolling is possible but rolls are not immediately available. Tools for extrusion can be produced for about $150 as compared to a cost for rolls that is many times this amount.

Finally, there are many instances where 1000 lb. or less of a shape are required at intervals over a long period of time. Large quantities would cause a large investment to be tied up in the user's inventory, whereas making small amounts as needed would require the rolling mill to reschedule its operations, which is prohibitively costly and disrupts mill schedules. In steel extrusion, the die is changed after every push so that successive pushes may well produce different shapes. Thus, an extrusion plant could produce an item as small as 150 lb. or work one small billet without costs becoming prohibitive, assuming that the demand for the item is recurrent so that the initial investment in the die is realized by repetitive small runs.

### Mechanical Limits

The mechanical limits on extruded pieces change as new tools are obtained and new tool arrangements are developed; consequently a definite tabulation of limits becomes obsolete soon after it is prepared. No attempt will be made here to present specific limits, but rather a description will be given of the factors which determine the boundaries, with a rough idea of the limits.

The minimum area of extruded piece depends on the container size, and the characteristics of the metal to be extruded, for each of these affect the pressure within the container. The metal may resist deformation at high temperature, or may be limited (by a tendency to break up) to a low temperature at which it resists deformation. The resistence to deformation, combined with the amount of deformation required to extrude from the large billet to the small extruded shape, determines the pressure in the container. Since the container pressure is limited by the tonnage of the press in large containers, or the strength of the tools in small containers, there is a lower limit to the size of an extruded piece which may be produced in any container.

The metal and the area of extrusion, then, determine which available container may be used. This container size puts a limit on the maximum diagonal dimension across the piece which will allow space between die opening and container wall to provide a strong enough die. It also dictates the maximum weight which can be extruded in one piece, since the billet diameter and length are determined by the container diameter and press stroke. Because of the complexity of these limitations each shape must be considered separately by the mill. However, as a rough guide for the designer, the limitations would be as follows:

| | |
|---|---|
| Minimum area | ⅜ sq.in. |
| Maximum diagonal | 6⅝ in. |
| Maximum weight | 400 lb. |
| Minimum web thickness | 0.100 in. |
| Minimum inside radius | 3/16 in. |
| Minimum outside radius | 1/16 in. |

Each one of these limitations assumes that metal type, area, and other conditions are optimum to reach the limit. On the other hand, new methods and tools are constantly arriving so that unless a limit is violated radically, the extrusion should be studied.

**Dimensional Tolerances** – Before generalizing on the tolerances available, it is best to point out some of the factors surrounding such a generalization. First, since dimensional error results from die wear, the strict limits to which tolerances are held are closely related to die costs for the extrusion. A "loose" specification will result in longer die life and lower costs. Second, since die wear produces dimensional variations, a section having small area (high extrusion ratio) causes high extrusion pressure, high die wear, and rapid dimensional variation, which is undesirable on a small section. Finally, certain portions of dies (such as sharp internal corners) wear more rapidly than other portions so that some dimensions in a specific shape will be more difficult to maintain than others.

To give a better general idea of what may be expected, sections having an area of 1 sq.in. or more, and having no sections under ⅜ in. thick, may be produced with reasonable die life to the tolerances for commercial hot rolled carbon and stainless steel grades. As the area and section thicknesses go up, this comparison will be more favorable to extrusion. Obviously it is preferable to treat each shape specifically, and frankly we have much to learn along this line at the present time, but it is our belief that the above generalization will at least give the designer something to work with.

**Economic Considerations**

The discussion of economic considerations and the outlining of fields of application of extrusion are closely related. Notice that the field of application that has been outlined for extrusion is the production of shapes that are not standard warehouse sections. This is dictated by economics.

Extrusion is expensive when compared to commercial hot rolling of standard items. To support this expense in the working of normal grades, the extruded product must give economies someplace else along the line. In the extrusion of stainless steel tubing for subsequent cold working, this saving results from the elimination of expensive grinding on the inside of the tubes. Other sources of savings may be in the increased yield of products from expensive materials which either break up excessively or suffer excessive chip loss in machining, or the saving may be from the elimination of extensive machining operations. If the latter is the source of the saving, it is generally necessary that the machine cutting time be high as compared with set-up time, because the extrusion tolerances will probably be such that set-ups and minor machining will still be necessary. By reducing the time spent in cutting, operating costs are decreased and the scrap losses in chips are eliminated.

Obviously the economic significance becomes less where a product is "unobtainable" from other sources. Such a product may be seamless tubes in grades such as 19-9 DL, 440-C, or pure titanium. Some of these items belong in the extrusion field because of their prohibitive cost to the mills or their prohibitive cost to produce.

## Alexander Littlejohn Feild

**Ⓜ Sauveur Medalist, 1954**

**Associate Director of Research, Armco Steel Corp.**

On page 244 of his A.S.M. book on "Stainless Steels", Carl Zapffe writes, "In marked distinction to all conventional processes, there is the special melting technique known as 'the rustless process', which is largely the result of the genius of A. L. Feild, to whom this book is dedicated."

The story of the rustless process is long and fascinating. The path by which Feild arrived at the basic invention in 1926 is a devious one; its development in the early 1930's is marked by Depression delays; its commercial exploitation has met with consistent and well-deserved success, not only for Feild's company but also for the entire economy of the stainless steel industry.

The first of a long series of papers published by this eminent metallurgist gave no indication of his future career – it was entitled "The Distribution of Ammonia Between Water and Chloroform" (he says now that he never did find out why this information was wanted), and was written while he was completing the work for an A.B. in physics at the University of North Carolina in 1911. The next title, in 1912, is even more remote from eventuality – "Notes on the Birds of Chapel Hill, N. C., With Particular Reference to Their Migration". But Feild was young, his scientific interests were wide, and after a year of teaching high-school science he turned to agricultural engineering, worked as assistant chemist in the North Carolina Agricultural Experiment Station, took a course in hydraulics and wound up with an M.S. in chemistry! During this period he became interested in the nitrification of soil and his professor suggested he take a Civil Service examination. Four months later he found himself at the Bureau of Mines in Pittsburgh studying iron blast-furnace slags. It was the agricultural engineers' loss, but the metallurgical profession's great gain!

His next publication was one of note: "A Method for Measuring the Viscosity of Blast-Furnace Slag at High Temperatures". This was published in 1916 when he was but 26 years old, and seven years later it brought Feild the first of a long list of honors – the Joseph E. Johnson, Jr. Award of the American Institute of Mining and Metallurgical Engineers.

Feild remained with the Bureau only three and a half years, leaving in 1917 for a job with National Carbon Co. in Cleveland. But his interest in iron and steel melting had gone too far to be dropped, so in two years he was transferred to Electro Metallurgical Co. in Niagara Falls.

Here it was, under the direction of F. M. Becket, that Feild first became involved in the burgeoning research on the physical chemistry of steelmaking, and on methods of bringing down production costs and improving quality. This interest was to take him through a series of transfers and new jobs (four years at the Long Island laboratories of Union Carbide and Carbon Corp.; two years at Central Alloy Steel Co. in Canton, Ohio; back to Union Carbide; a period with Simonds Saw and Steel Co. of Lockport, N. Y.), culminating in his association with the Rustless Iron Corp. of America in 1931, where Feild's 1926 pilot-plant work on his stainless steel process in Canton was brought to commercial success.

The story of the Rustless process – based on the melting of cheap (high-carbon) ferrochrome, stainless steel scrap and chrome ore on a chromite hearth lining – is interestingly told in Zapffe's book mentioned at the outset, briefly by Feild himself in the 1936 edition of "The Book of Stainless Steels", and at greater length in a paper on "Experience With Chromite Hearth" presented by the inventor before the Electric Furnace Steel Conference of the A.I.M.E. in 1951. In conversation, Feild tells the story with fond nostalgia, but space does not permit tracing in detail how pilot operations were started at Central Alloy Steel Co. in 1926, how the promising plans for development at Simonds Saw and Steel collapsed in the depression, and how in 1931 he moved to Baltimore and placed his stainless steel melting process in successful commercial operation at the plant of the Rustless Iron Corp. of America, despite the burdensome patent litigation with which this company was then contending. This company had been sued in 1929 for patent infringement by a patent-holding company now defunct. The case dragged on for five years. Although Feild took an active part in successfully defending his company, his own inventions and patents were not under attack nor any way involved in litigation.

Feild served as consulting metallurgist and later as director of research for the reorganized Rustless Iron and Steel Corp. in Baltimore until its merger with Armco Steel Corp. in 1946, when he was named associate director of research for the parent company. His interest is still in stainless. Not one to rest on his laurels, he has stimulated much work during the intervening 20 years on new grades of stainless steels and developments in process metallurgy. Notable is the development of the PHR (precipitation-hardening) grades which can be fabricated as received and subsequently age hardened with little danger of scaling and distortion. Likewise, Armco's Balti-

more Works, using the Rustless process, first produced commercially the extra-low-carbon grades melted in standard electric-arc furnaces.

It is not only his early basic discoveries but this continued stimulation of fundamental scientific studies that earned Alec Feild the Albert Sauveur Achievement Award for 1954, one of the highest honors bestowed by the American Society for Metals. Others of which he is justly proud are the "Modern Pioneer Award" of the National Association of Manufacturers in 1940; a Certificate of Appreciation for Patriotic Civilian Service to the Department of the Army (for overseas technical intelligence service in Germany in 1945); a certificate from the Office of Scientific Research and Development (for participation in work of the National Defense Research Committee); and an Honorary Degree of Doctor of Science awarded by Stevens Institute of Technology.

In A.S.M. he is a past chairman of the Baltimore Chapter, and has served on the national Publications Committee. In the A.I.M.E. he has been vice-chairman of the Iron and Steel Division, member of the Executive Committee, chairman of the Committee on Physical Chemistry of Steelmaking, chairman of the Papers and Programs Committee. He also finds time for participation in a dozen or so other technical and professional organizations.

Withal, Alec Feild has not neglected his early interests in ornithology and agriculture. To-

# Book Review

MODERN ELECTROPLATING, Allen Gray, Editor; Second (revised) edition, 563 p. John Wiley & Sons, Inc., New York, 1953. $8.50. Chapman & Hall, Ltd., London, 68s.

HANDBOOK OF INDUSTRIAL ELECTROPLATING, by E. A. Ollard and E. B. Smith, Second (revised) edition, 366 p. Iliffe & Sons, Ltd., London, 1954, 30s.

## Electroplating

*Reviewed by D. GARDNER FOULKE**

THESE TWO books are being reviewed jointly because of their complementary nature. "Modern Electroplating" represents an approach to electroplating from the aspect of baths and their control, while the "Handbook of Industrial Electroplating" is concerned primarily with engineering and equipment problems. Unfortunately, the two books do not provide a complete bookshelf for the American electroplater or engineer.

"Modern Electroplating" is a surprisingly well-integrated description of present-day knowledge of electroplating solutions when one considers that it is the work of 39 authors, all of whom, incidently, are experts. However, there were bound to be certain areas less well done than others. The first chapter on general principles will certainly be judged inadequate by the theoretical electrochemist and the second chapter on laboratory methods of control is not very useful to the practical plater because of lack of details. However, as with all chapters of the book, generous reference to the literature renders such criticism less important.

All of the commonly deposited metals are taken up in alphabetical order and their plating is explained by describing principles of bath operation, bath composition, operating conditions, anodes and the basic analytical methods. The preparation of the basis metals and physical properties of the electrodeposits are less thoroughly covered, which is in keeping with the primary objective of the book – a description of plating electrolytes and the factors influencing the deposition process, such as composition, impurities and addition agents.

The deposition of some 30 uncommon metals, documented by more than 300 references, is described in a separate chapter. The last chapter pertains to the electroplates commonly applied to aluminum and magnesium and it might well have contained information on direct chromium plating of aluminum.

"Modern Electroplating" is a book that anyone concerned with electroplating solutions and their

*Manager, Electrochemical Development, Hanson-Van Winkle-Munning Co., Matawan, N.J.

gether with his wife, Jane Ethel McKeel Feild, also a North Carolinian, he sees to it that their home in Baltimore is surrounded by gardens, well populated with birds. He admits that he quit taking work home from the office a few years ago and now has more time for reading. Here again his tastes are varied with a penchant for poetry, Masefield being a favorite. He takes his sports by promoting Little League baseball in which his youngest son, Robert, is a star performer. Three older sons by a previous marriage are Alexander L. Feild, Jr., a metallurgist with du Pont working on titanium; Richard, a research chemist with Procter & Gamble; and James, who has recently completed his sophomore year at Johns Hopkins University.

Feild was born at Oxford, N. C. on Nov. 14, 1890, son of Alexander Jones Feild and Louise Rutledge (Hughes) Feild. While his father practiced his chosen profession of law until his death in 1942, there were brief ventures into other fields such as the organization and management of a box manufacturing concern and the publication of a weekly newspaper. He was a descendant of James Feild who sailed from England in 1624 and settled in Henrico County, Va.

In spite of this southern background Feild says that by virtue of an early departure from his native state and his sojourn in various parts of Pennsylvania, Ohio and New York, old friends insist that he has become a thorough "Yankee" even though a Marylander by adoption.

M. R. Hyslop

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control should find sufficiently useful to make room for on his book-shelf; certainly it should be in the library of every organization interested in electrodeposition.

The "Handbook of Industrial Electroplating" is directed more toward the engineering and production aspects of electroplating than to electrolytes and electrochemistry. As such it should be a companionpiece to "Modern Electroplating". However, British and American practices differ sufficiently to cause this reviewer to look forward hopefully to the early release of a publication of this sort by American authors.

The various chapters describe electrical equipment, the deposition plant, water and drainage, solution formulas, analysis, purification of solutions and safety precautions. The chapter on electrical equipment, the best in the book, includes an interesting description of a constant controller for current density which apparently is more widely used in Great Britain than it is in the United States.

Where the authors could not rely upon suppliers to provide detailed information the coverage is general. For example, the section on plating tanks could have been more specific as to the best tank (or tanks) for each solution encountered by the plater and should have mentioned riveted steel tanks. This superficial treatment is characteristic. The authors manage to fill a whole page to impress upon the reader the importance of proper swilling (rinsing), concluding that "the only satisfactory method is to adjust the flow of water in a swill tank to the quantity which has been previously found to be satisfactory". Countercurrent flow and formulas applicable thereto are ignored, as are methods to decrease drag-out which reduce rinse water requirements. On the other hand, where suppliers submitted full information, the description becomes quite detailed. However, one wonders after reading about a number of pumps and filters, including a spare parts list for one pump, just what equipment to use or, more important, what capacity equipment will be adequate for a particular plating bath.

The errors and omissions in the chapters concerned with solutions will not be enumerated, because this section of the book is practically useless anyhow. More complete data may be found in many plating handbooks and the authors would have been wiser had they omitted this section and expanded the engineering and operational portion of the book to include more details on plating-room layout, rack design, diaphragm engineering and purification methods.

Very few references are given, and this may lead to the erroneous conclusion that the book is rather complete within itself. Finally, it is unfortunate that matters as easily checked as the addresses of the American Electroplaters' Society and the Electrochemical Society are in error and that a magazine as important in the field as *Plating* is not mentioned in the list of periodicals.

It is sincerely hoped that the American counterpart of the "Handbook of Industrial Electroplating", published last month, will be deserving of kinder treatment than this reviewer feels he can grant the attempt of Messrs. Ollard and Smith to fill a very real need — a good plating engineering handbook.

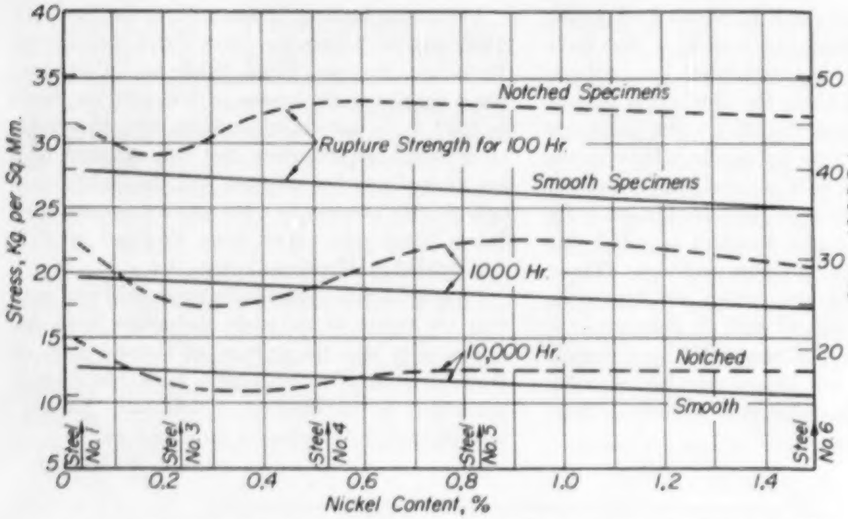


*Fig. 1 – Effect of Nickel on Stress-Rupture at 550° C. for 100, 1000 and 10,000 Hr. of Cast and Heat Treated Steel Containing 0.13% C, 0.5% Cr and 0.8% Mo*

# Better Steel Castings for High-Temperature Plant

*By W. SIEGFRIED and F. EISERMANN**

**Heat treated mild steel castings with low chromium and molybdenum, used in high-pressure steam boilers and turbines, have been improved by vanadium additions, and their tendency toward notch sensitivity has been corrected by minor amounts of nickel and copper.**

Steel castings which must be absolutely reliable when performing at relatively high temperature and stress are required for steam boiler parts and for turbine casings. In Europe such castings ordinarily are of low-alloy steel containing between 0.5 and 1.0% chromium and molybdenum. Specifically, Sulzer Bros. of Winterthur have usually employed for these purposes a cast steel closely approximating the following analysis: 0.13% C, 0.7 Mn, 0.5 Si, 0.5 Cr, 0.8 Mo.

High-pressure steam equipment is now expected to be in service for longer and longer time. This requires materials of higher creep resistance and freedom from any damage by embrittlement, either by heat treatment during fabrication, by long time at high temperature and stress, or by unavoidable fluctuations in service conditions. In an attempt to improve the basic steel mentioned at the outset, we have added 0.2% vanadium to it, but have been disturbed by the "embrittlement" sometimes observed in our laboratory tests on the material. By "embrittlement" we mean that creep tests on notched bars will yield lower rupture strengths than creep tests on smooth bars.

An extensive research into this matter has therefore been instituted in Sulzer's engineering laboratory, and the following brief note will describe some results already achieved – particularly the role of a moderate amount of nickel and copper on the creep properties of our basic steel, vanadium-free. Other studies determined the

*Engineering Dept., Sulzer Bros., Ltd., Winterthur, Switzerland.

effect of nickel and copper on these cast steels containing 0.2% vanadium.

At the outset of the program an 1850-lb. melt was made of Swedish material plus necessary ferro-alloys to analyze 0.13% C, 0.50 Si, 0.70 Mn, 0.50 Cr, 0.80% Mo. Incidental impurities were 0.007% P, 0.005 S, 0.03 Ni, 0.03% Cu. This charge was melted in a medium-frequency electric furnace and split into 12 equal parts. One had no additions; it was the standard of comparison, representing our old standard practice. The other portions of present interest are noted in Table I, which shows the additions and the quenching temperatures.

After casting into appropriate test pieces these steels were first annealed at 2010° F. (1100° C.) for 5 hr. and cooled in the furnace. (Steels 9 to 12 inclusive were cooled in mineral wool.) Hardening was done by heating to 50° C. above the critical range – the temperatures are noted in the table – holding for 2 hr. and quenching in oil. Subsequent tempering of all samples was then done at 1325° F. (720° C.) for 6 hr. and quenched in water.

Creep tests on smooth and notched specimens were then made on samples of all these analyses. Some of the tests have continued over 5000 hr. Stress for fracture after 100, 1000, 5000 and 10,000 hr. was then estimated by interpolation and extrapolation. Figure 1 shows the results obtained at 550° C. for vanadium-free steels, the stress for fracture after 100, 1000 and 10,000 hr. being plotted against the nickel content. It is evident that there is a tendency to embrittlement (reduced rupture strength) when nickel is 0.2 to 0.3%, although this is not very pronounced. At higher nickel contents this disappears completely, and the notched specimens then have considerably greater rupture strength than the smooth specimens.

**Table I – Additions to the Basic Composition and Quenching Temperatures**

| No. | Addition | Quench |
|---|---|---|
| 1 | None | 1830° F.; 1000° C. |
| 2 | 0.2 V | 1830° F.; 1000° C. |
| 3 | 0.2 Ni | 1795° F.; 980° C. |
| 4 | 0.5 Ni | 1740° F.; 950° C. |
| 5 | 0.8 Ni | 1740° F.; 950° C. |
| 6 | 1.5 Ni | 1670° F.; 910° C. |
| 7 | 0.5 Cu | 1740° F.; 950° C. |
| 8 | 0.2 Ni, 0.2 Cu | 1740° F.; 950° C. |
| 9, 10 | 0.5 Ni, 0.3 Cu | 1690° F.; 920° C. |
| 11 | 0.5 Ni, 0.2 V | 1780° F.; 970° C. |
| 12 | 0.5 Ni, 0.3 Cu, 0.2 V | 1780° F.; 970° C. |

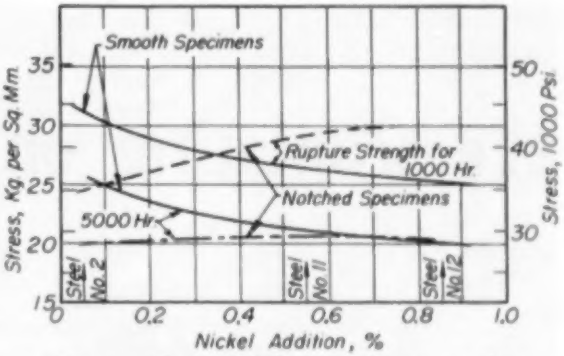


*Fig. 2 – Effect of Nickel and Copper on the Steel of Basic Composition Plus 0.2% Vanadium*

In order to determine the corresponding influence of copper in such steels, steels 7, 8, 9 and 10 were formulated and tested in the same way. Stress-rupture values for fracture after 100 and 1000 hr., when plotted as a function of the sum of nickel and copper are the same as those for nickel alone (Fig. 1) within the limit of experimental error. Figures for fracture after 10,000 hr. are not available, as the creep testing program is not yet completed. A preliminary conclusion – to be verified by further tests – is that copper and nickel have roughly the same effect on "embrittlement" or notch sensitivity in high-temperature, high-pressure service of these low-alloy steels.

**Influence of Vanadium** is interesting, as shown in Fig. 2 wherein are plotted stress-rupture results on steels 2, 11 and 12 of Table I. In the first place, the influence of vanadium on the basic steel composition itself is shown by comparing values for steel No. 1 in Fig. 1 and steel No. 2 in Fig. 2. Vanadium (0.2%) raises the rupture strength of smooth specimens for 1000 hr. at 550° C. from 19.5 kg. per sq. mm. (28,000 psi.) to 31 kg per sq. mm. (44,000 psi.). Steel No. 2, containing only traces of nickel and copper (about 0.03% of each) is markedly "brittle" in that the creep strength of notched specimens is 6 or 7 kg. per sq. mm. (8500 to 10,000 psi.) lower than smooth specimens. However, 0.5 to 1% nickel is sufficient to eliminate this feature.

This point is of the greatest interest, since additions of nickel often lead to embrittlement in steels which have been heat treated to a high strength level. If the steels are tempered at a high temperature this tendency to embrittlement is lessened by adding 0.5 to 1% nickel, and this applies both to Cr-Mo-V and to Cr-Mo steels.

# Electroplating on Magnesium

*By H. K. DeLONG**

**The success of electroplating magnesium is dependent almost entirely on using a preplate of zinc and on the adhesion and uniformity of this initial coating. Subsequent coatings can be applied according to standard plating practice.**

ELECTROPLATES on magnesium have proved their usefulness in three fields of application: where a bright, tarnish resistant finish for decorative effect is required, where wear resistance is a prime requisite, or where galvanic corrosion is a problem.

The use of plates on magnesium for decorative effect needs little explanation. Such applications of plated magnesium can be found in automobiles, transcribing machines and rule cases.

The most outstanding application of plated magnesium where resistance to wear is needed is in the printing industry. The cylinders for printing business forms, drinking cups, and labels must withstand many impressions during the press runs. Plated magnesium cylinders have printed millions of impressions and are still serviceable.

The third reason for electroplating on magnesium is to prevent galvanic corrosion when magnesium is used in a dissimilar metal couple. Magnesium must be separated from most dissimilar metals either by inserting tapes or sealing compounds in the joint or by painting both metals – or it may be plated to bring it to the same potential of the other metal. The minimum plate for galvanic corrosion is 0.0005 in. copper and 0.001 in. nickel, with flash chromium being optional. For a longer protective life it is desirable to use 0.0005 in. copper, 0.001 in. nickel, and a coat of paint, the latter improving the resistance to corrosion.

**Electroplating Procedure** – The Dow process for electroplating on magnesium as evolved by the Dow Chemical Co. consists of first laying down a thin zinc coating by chemical reduction, followed by an electrodeposit of copper in a copper cyanide bath. After this copper strike has been applied, other metals can be electrodeposited in the customary manner. The procedure and some of the requirements are given in Table I on p. 108.

Proper surface preparation of the magnesium part, including degreasing and pickling, is necessary in order to secure the clean homogeneous surface required for the zinc coating. The operations required for the electroplating of magnesium may be summarized as follows:

1. Surface conditioning.
2. Activating.
3. Zinc immersion coating.
4. Copper plating.
5. Subsequent plating (using standard procedures).

### Surface Conditioning

The surface preparation depends on whether the magnesium is in cast or wrought form, the condition of the part, and the type of surface desired after electroplating. The surface must be free of heavy oxide layers, mill scale, graphite-base lubricants such as used during forming or forging, previously applied surface conversion coatings, inverse segregation of aluminum with alloys containing a high content of the alloying element. To clean a surface of these contaminants, the surface should be pickled, or pickled and then mechanically cleaned. Work that is to be mechanically finished, as by polishing or buffing, usually does not need pickling.

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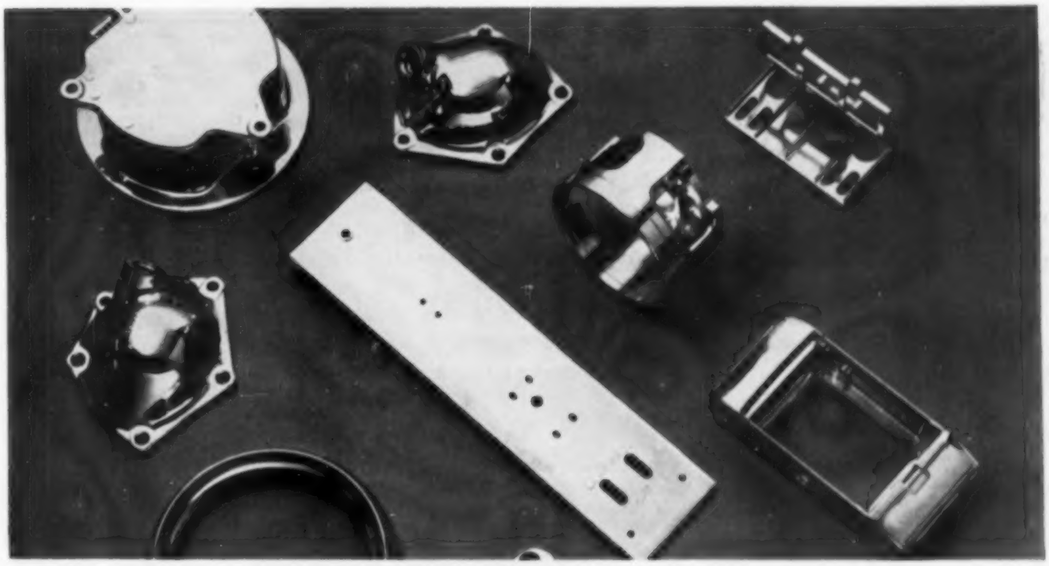


*Fig. 1 – Typical Magnesium Die Castings With Decorative Chromium Plates*

If a smooth and highly polished surface is required, the parts are wheel polished and then buffed. Small parts may be tumbled and burnished. Special surface effects may be produced by sand-blasting prior to electroplating. Such surfaces are highly reactive and need to be pickled before plating. The technique used for preparing zinc-base die castings for electroplating is usually suitable for magnesium.

Grease, buffing compounds, and similar oily matter must be removed prior to acid pickling and after the mechanical operations. The cleaning methods for magnesium are the same as normally used on mild steel; namely, solvent rinsing, vapor degreasing with chlorinated solvents, solvent emulsion cleaning or alkaline cleaning. The preferred alkaline cleaners are of the heavy-duty type that contain caustic soda and the other necessary ingredients. Magnesium may be cleaned cathodically in alkaline solutions but anodic cleaning is not practical because a film forms on the surface of the metal when it is made the anode in an alkaline electrolyte.

Of the number of acid pickling methods available for the removal of contaminants from magnesium surfaces, the following processes are those found to be most suitable for use prior to plating operations. These pickling methods are suggested as being most suitable in the interest of a low dimensional loss and the maintenance of surface smoothness during pickling:

*Castings* – Sand, permanent mold and die castings are pickled ¼ to 3 min. at room temperature in either *(a)* a solution of chromium trioxide, 280 g. per l.; 70% nitric acid, 25 ml. per l.; hydrofluoric acid, 8 ml. per l.; or *(b)* undiluted solution of 85% phosphoric acid.

*Wrought Forms* – Sheet, extrusions, forgings, and sheet-formed parts are pickled ⅛ to 2 min. at room temperature in either *(a)* a solution of chromium trioxide, 180 g. per l.; sodium nitrate, 30 g. per l.; calcium fluoride, 2.5 g. per l.; or *(b)* glacial acetic acid, 28 ml. per l.; sodium nitrate, 80 g. per l.

*Special Requirements* – If no dimensional change can be tolerated or a sharp detail must be maintained, as with printing plates and rolls, the work is cleaned for 2 to 10 min. (time will vary with the bath temperature and degree of cleaning required) in a solution of chromium trioxide, 180 g. per l., at room temperature to boiling.

**Activating** – Just prior to the application of the zinc immersion coating it is necessary to activate the surface so that a uniform coating will form. This requires a special pickling treatment for removing any thin films left by the preceding pickling or degreasing operations and for removing any slight etching (which might cause a roughness in the subsequent electrodeposits). The method of activating magnesium surfaces to receive the zinc coating is:

Parts are immersed for 2 min. at 70 to 90° F. in an aqueous bath of the following composition:

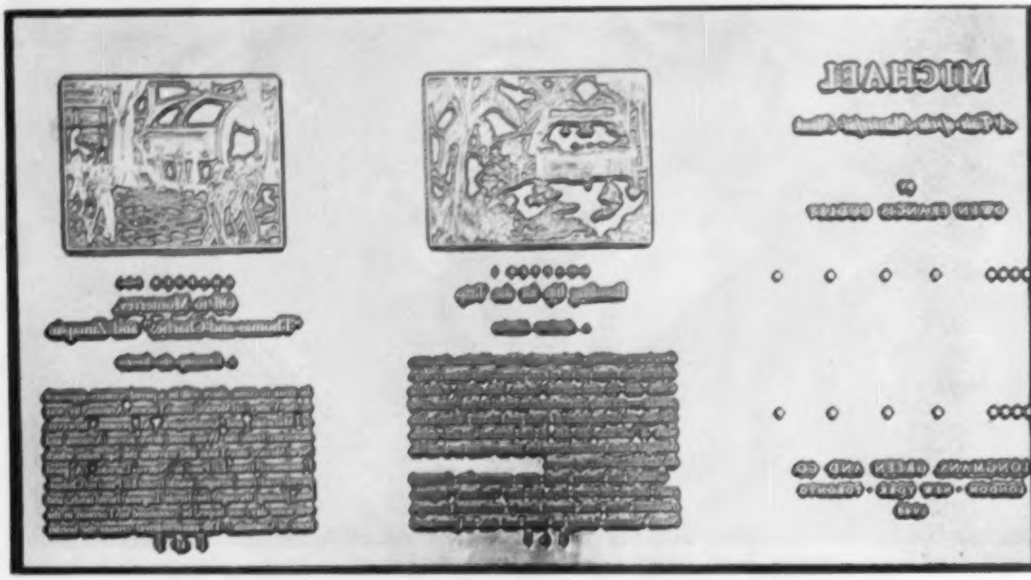


*Fig. 2 – Magnesium Printing Plate Electroplated With Hard Chromium*

phosphoric acid, 200 ml. per l.; sodium, potassium or ammonium bifluoride, 100 g. per l.

**Preliminary Plates**

**Zinc Immersion Process** – Magnesium, being less noble than any of the other common metals, readily replaces many of them from solutions of their salts by chemical reduction. In acid solutions the immersion coatings are usually nonadherent and powdery. In strongly alkaline solutions the coatings are more adherent but still not enough so to provide a base for electrodeposits. Aqueous solutions of most alkaline compounds do not dissolve the magnesium hydroxide layer always present on the magnesium surface and, therefore, cause little or no attack of the magnesium surface above a pH of about 10.6. An exception to these is the class of aqueous solutions of the pyrophosphates. Pyrophosphates will readily react with magnesium oxide and magnesium hydroxide to form water-soluble complexes, particularly at a hydrogen ion concentration below approximately pH 11.0. It was through the discovery that pyrophosphates react with the ever-present oxide or hydroxide surface films that a method of zinc immersion coating was developed. By effecting the normal film removal under specific conditions in a pyrophosphate solution in which a metallic salt is also present, an adherent metallic deposit can be obtained by chemical reduction. The metallic film is intimately bonded to the magnesium surface because it is applied to a surface that has been freed of oxide by the initial reaction with the pyrophosphate. Once the surface is free of oxide, the zinc film forms slowly until a continuous coating about 0.0001 in. thick is formed. When the zinc coating is completely formed on all areas, the reaction in the zinc pyrophosphate bath subsides. (If it did not subside the original coating would be undermined and loosened by the continuous formation of the zinc.)

The quality of the zinc coating is, to a marked extent, dependent on the rate of deposition and also the ratio of zinc to pyrophosphate. Since a rapid deposition results in coatings having poor adherence, various chemical compounds were investigated as inhibitors to control the reaction. It was found that fluorides in small amounts were effective and also produced a zinc deposit of finer grain. The pH of the zinc bath is also a consideration as is the use of carbonates in adjusting and maintaining this factor in the proper range.

**Standard Zinc Coating** – The bath most widely used has the following composition:

| | |
|---|---|
| Zinc sulphate, monohydrate | 30 g. per l. |
| Tetrasodium pyrophosphate | 120 |
| Potassium fluoride | 7 |
| or Sodium fluoride | 5 |
| Sodium carbonate | 5 |

The bath is prepared by first dissolving the zinc sulphate in water at room temperature. The solution is heated to 140 to 180° F. and the tetrasodium pyrophosphate is slowly added while the solution is stirred. A white fluffy precipitate (sodium zinc pyrophosphate) forms, but this dissolves after stirring for 5 to 10 min. or longer, depending on the temperature and degree of agitation. After the precipitate is dissolved, the fluoride is added, then the carbonate. Additions of the latter are in amounts that will adjust the pH to a range between 10.0 and 10.6 (a range of 10.2 to 10.4 is generally preferred). The pH values used here are those obtained by colorimetric methods; values for electrometric methods (with a standard glass electrode) should be 0.5 pH lower.

The bath is operated at 175 to 185° F. and is mildly agitated during use to avoid stratification, particularly when water is added to replace losses by evaporation. The time for treatment is 3 to 10 min., being dependent upon factors such as alloy composition, bath temperature, freshness of the baths, and method of surface preparation. Optimum times for treatment of various alloys are generally as follows:

| | |
|---|---|
| Aluminum-containing alloys | 5 to 7 min. |
| Alloys containing no aluminum | 3 to 5 min. |
| Unalloyed magnesium | 3 to 5 min. |

The time should be no longer than required for complete coverage of the surface with a continuous zinc coating. Prolonging the treatment may result in less adherent deposits.

The water for this plating bath should be reasonably free of iron and other heavy metal salts. Tap water may be used but deionized water is to be preferred to assure a proper purity. The bath must not be excessively contaminated with solutions of other heavy metal salts from other plating operations. Chromium is particularly detrimental, as even small amounts inhibit the reduction of zinc at the magnesium surface.

In the zinc immersion process the zinc metal and pyrophosphate concentration do not need to be held to close limits. The fluoride concentration needs careful attention. The fluoride, as mentioned previously, controls the reaction rate of the solution. While acceptable coatings have been obtained in fluoride-free baths, the fluoride allows a much greater degree of flexibility in the concentration of other bath components as well as in the treatment time for producing a satisfactory coating of zinc. The 0.5% sodium fluoride or 0.7% potassium fluoride concentration is maximum for baths for all conventional magnesium alloys. For unalloyed magnesium, the fluoride content should be about one-half of the normal concentration. If the fluoride is increased beyond the normal amount, deposition is slowed and thinner zinc coatings form. The thinner coatings do not give as good adherence of subsequent electrodeposits. The normal thickness of the zinc plate is approximately 0.0001 in.

**Copper Plating** – Immediately after the application of the zinc coating the work is transferred to a cyanide-type copper bath. The thickness of the copper deposit depends on the subsequent plate and the kind of bath in which it will be plated. When the subsequent plating is to be in an alkaline bath, then the copper deposit is 0.0001 in. or less; in an acid-type bath, deposits of a minimum thickness of 0.0003 in. are required to protect the magnesium surface from chemical attack. The following copper cyanide bath has been found satisfactory for copper striking and plating over the zinc immersion coating:

| | |
|---|---|
| Copper cyanide | 41.3 g. per l. |
| Sodium cyanide | 50.8 |
| Sodium carbonate | 30.0 |
| Rochelle salt | 45.0 |
| Sodium hydroxide | 7.5 |
| Free cyanide | 5.6 |
| Operating temperature | 150 to 160° F. |
| pH (colorimetric) | 12.2 to 12.8 |
| Cathodic agitation, ft. per min. | 8 to 12 |

Electric contact is made quickly and a high current density of 30 to 40 amp. per sq.ft. is applied for the first 30 sec. to 1 min. if deeply recessed parts are to be plated. Prolonged striking at high current density is avoided as it may cause inferior adhesion and, subsequently, blistering. After 30 sec. to 1 min. of deposition, the current is decreased to 15 to 25 amp. per sq.ft. and plating is continued. Parts of average shape (those not having deep recesses) do not require an initial high current density. The work may be plated to the desired copper thickness in the above solutions or it may be transferred, after an initial plating period of 5 min., to a conventional high-efficiency bright-copper bath of the cyanide type.

Periodic current reversal is advantageous with this copper bath. Using a 15-sec. forward and 3-sec. reverse plating cycle, bright smooth deposits may be obtained, thus eliminating a further copper plating step for maximum brightness. In using periodic current reversal it is preferable to plate on the forward cycle for the first 30 sec. to 1 min. and then apply the alternating forward and reverse cycle. This procedure

*Fig. 3 – Installation for the Production Plating of Magnesium (Courtesy of Goddeyne Mfg. Co.)*

builds up an initial layer of copper before deplating occurs.

All operations involving the use of aqueous solutions in the foregoing steps of cleaning, pickling, zinc coating, and copper plating are, of course, followed by adequate and thorough water rinsing. The rinse waters must be kept free of heavy metal plating salts when used for rinsing after any pickling and the zinc coating procedures. After zinc coating, and prior to copper plating, the zinc coating should be rinsed in cold water only.

Copper can be plated in heavier deposits by prolonging the time in the initial bath, or by transferring the work to other alkaline copper cyanide or pyrophosphate baths. The proprietary cyanide type requires no modification for use on magnesium. With the pyrophosphate type it has been found advantageous to add 30 to 60 g. per l. of potassium fluoride to minimize chemical attack, thus permitting thinner strike coatings of copper to be used.

**Final Plates**

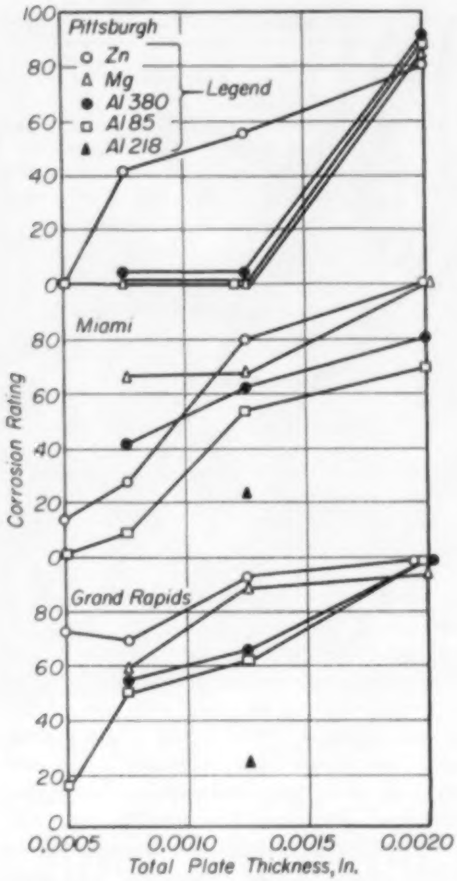
**Nickel Plating** – Nickel may be plated from any of the conventional baths once an adequate thickness of copper has been applied. A minimum thickness of at least 0.0003 in. of copper is usually required on all surfaces when the nickel plating is done in the Watts-type bath.

For the plating of tubing and deeply recessed parts, a nickel bath has been developed that does not seriously attack magnesium surfaces that are devoid of the initial copper deposit or in areas where the copper is abnormally thin. The composition and operational requirements of this bath are:

| | |
|---|---|
| Nickel sulphate | 60 g. per l. |
| Boric acid | 35 |
| Ammonium fluoride | 65 |
| or | |
| Ammonium bifluoride | 50 |
| Wetting agent | 0.05 |
| Hydrofluoric acid (when needed to reduce pH of bath to pH 5.5) | |
| Operating temperature | 115 to 125° F. |
| Current density, amp. per sq.ft. | 5 to 15 |

**Chromium Plating** – Decorative copper-nickel-chromium deposits can be applied, or chromium applied after copper striking for applications where wear resistance is of primary importance. The chromium is electrodeposited from the standard chromic acid baths now in use.

**Other Electrodeposits** – Generally, any of the other metals that are normally applied by electrodeposition can be applied once the copper plating is completed. Brass, cadmium, zinc, silver and gold have been electrodeposited on the copper plated magnesium by using standard practices. Zinc and brass have been electrodeposited from cyanide baths directly on the zinc immersion coated surface. In using these baths for plating directly on the zinc immersion coating, immediate electrical contact must be made as the work enters the bath.



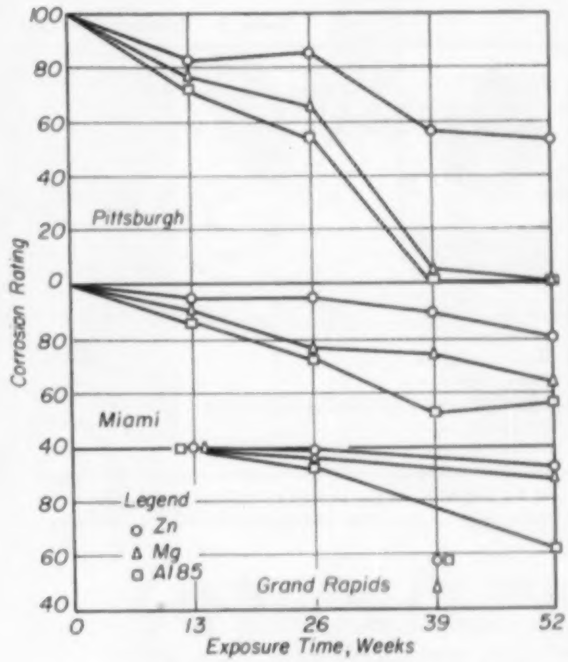




*Fig. 4 – Comparative Results of Exposure Tests of Cu-Ni-Cr Plates of Varying Thickness on Aluminum, Magnesium and Zinc. Exposure time was 1 year at each test site*

*Fig. 5 – Effect of Exposure Time on Corrosion Test Results for Cu-Ni-Cr Plates. Thickness on each panel was 0.00125 in.*

**Plating Equipment and Its Use**

**Barrel Plating** – Small magnesium parts can be batch processed by barrel plating methods common to other metals. The zinc coating is best applied in a plating barrel that is revolved very slowly or intermittently during the treatment. The barrel must be insulated from the metal tank. No particular difficulty has been experienced with scratching of the thin zinc coating, or loss of electrical contact during the subsequent copper plating of the coated parts. Generally, the electrodeposits are scratched less during the plating operations on these lighter loads than are equivalent batches of heavier steel parts.

**Racking** – Certain requirements must be observed in the racking of magnesium parts to insure the proper formation of the zinc coating. Standard structural metals for making plating racks, such as copper, steel and phosphor bronze, are cathodic to magnesium. If the ratio of exposed cathode area of such racks is large in proportion to the anodic area of the magnesium part, a suitable zinc coating will not be formed. This occurs adjacent to the rack contact areas and on areas of high current density, such as on sharp edges of the work. Conventional non-magnesium racks may be used. However, organic coatings for racks are usually necessary. The racks used in electroplating metals other than copper, brass, zinc or cadmium should be given a copper strike after each plating cycle before recycling. Parts usually can be wired with fine copper, brass or phosphor bronze wire when required, without the necessity for organic coating, as a means of providing electrical contact. This is a satisfactory method for work of small size, or of a quantity too small to warrant the construction of racks.

**Properties of Electrodeposits**

**Adhesion** – The adhesion of the electrodeposits appears to be good – equivalent to that normally obtained with good practice on

**Table I – Procedure for Electroplating Magnesium**

| Operation | Treating Time, Min. | Temperature of Bath, ° F. | Tank Material | Remarks |
|---|---|---|---|---|
| Alkaline cleaner | 3 to 10 | 190 to 212 | Steel | Solvent or mechanical cleaning, or both, optional prior to this step, depending on type of surface required. |
| Pickling | ½ to 2 | 70 to 90 | Ceramic or stainless steel* | Choice of several pickling solutions available. See text. |
| Cold water rinse | — | — | Steel | |
| Activating | 1 to 5 | 70 to 90 | Rubber or vinyl-base synthetic lining | |
| Zinc immersion coating | 3 to 5 | 175 to 185 | Stainless steel or rubber-lined tank† | Solution should be mildly agitated. |
| Cold water rinse | — | — | Steel | |
| Copper strike | 6 | 150 to 160 | — | Cathodic agitation suggested. |
| Cold water rinse | — | — | Steel | |
| Plating baths | — | — | — | Applied according to standard commercial plating practice. |

*Mixture of chromic, nitric and hydrofluoric acids requires a vinyl-base synthetic rubber lining.
†Heating coil should be stainless steel with stainless steel tank, or heavily nickel plated with rubber-lined tank.

zinc-base die castings. No quantitative data on this property are currently available. However, wrought products plated with copper-nickel-chromium have withstood heating to the melting point of the magnesium basis metal (about 1200° F.) without a general lifting or blistering of the deposit. Cast parts will withstand heating up to 450° F. and occasionally higher, depending on the porosity and other factors of quality of the casting. Adhesion determinations by physical deformation (such as by hammering, bending or breaking) have been used to study this property qualitatively.

**Corrosion Resistance** – Magnesium, being anodic to other metals that are electrodeposited, normally would be expected to corrode preferentially to the electroplate, unless the deposit was pore-free. This has been found to be more or less the case when copper or nickel are applied directly on magnesium. It is interesting and quite encouraging to note that the use of an initial layer of zinc to separate the more noble metal deposits from the magnesium improves the protective value of subsequent electrodeposits because the galvanic effect between the final plate and magnesium is greatly reduced.

The electrodeposits on magnesium have been quite extensively investigated for their protective value in various accelerated and natural corrosion environments. On the basis of these results it can be stated that electroplating on magnesium is a practical means of securing a good degree of corrosion and tarnish resistance and is consistent with the protection given by plates on other nonferrous metals such as aluminum and zinc.

A recent investigation of the protective value of copper-nickel-chromium electrodeposits, in a cooperative testing program with one of the large automobile companies and a die casting concern, has shown that magnesium has performed well when compared with similar plating on zinc and aluminum. The specific objectives of this project were to determine how decorative chromium plates on zinc, aluminum and magnesium alloy die castings compare as to rate and type of corrosion when exposed to different exterior atmospheres.

The findings in this project as regards the relative corrosion performance of the plating over different basis metals appear to be fairly clear cut. (It should be kept in mind that the plating of aluminum and magnesium alloy castings is relatively new as compared to plating of zinc.) Much has already been done to produce zinc alloys for die castings of plating quality, and surfaces can be produced that are relatively homogeneous.

The original die-cast panels of both the magnesium and aluminum showed minor defects, such as flow lines, laps and some porosity. These minor defects, while of little or no consequence in normal applications of bare or painted surfaces, obviously could affect the corrosion resistance of the coating, particularly of thin electrodeposits; heavier deposits cover these defects by forming a more continuous and pore-free protective coating.

**This Set of Dies,** for forming attachment ends, has remarkable toughness imparted by nickel. As a result, these dies can withstand heavy-duty service for long periods in the field.

**Drill Steel Showing Shank** formed by an I-R Drill Steel Sharpener. The attachment end, also forged by the machine, is shown after threading.

**Nickel Alloyed Steel Dies** contribute to both efficiency and economy of Drill Steel Sharpeners like this Ingersoll-Rand Model 54 . . . a type which often serves in remote parts of the world, where repair and replacement parts are sometimes difficult or impossible to obtain.

# How Ingersoll-Rand extends life of Drill Steel Sharpener dies

Operated by compressed air, I-R Drill Steel Sharpeners not only form shanks and attachment ends on Jackrods, but are also used to turn out a variety of other small forgings needed in the field.

Accordingly, you can appreciate why all dies, formers, dollies and the like . . . supplied for this work . . . must have ample stamina for repeated use on the job.

And for this repeated use, Ingersoll-Rand produces these vital parts in a die steel containing from $1\frac{1}{2}$ to 2% nickel.

The addition of nickel imparts toughness, along with ample strength and hardness. This combination of properties in a die enables the user to turn out uniform, accurate, true-to-shape forgings rapidly. For example, on one of the larger units, it is possible to forge as many as 50 shanks an hour.

This is one more example of the way nickel, either alone or in combination with other alloying elements, makes possible controlled improvement of specific properties. For the best set of properties to improve your products or equipment, look to alloys containing nickel. Send us details of your metal problem for our suggestions. Write us today.

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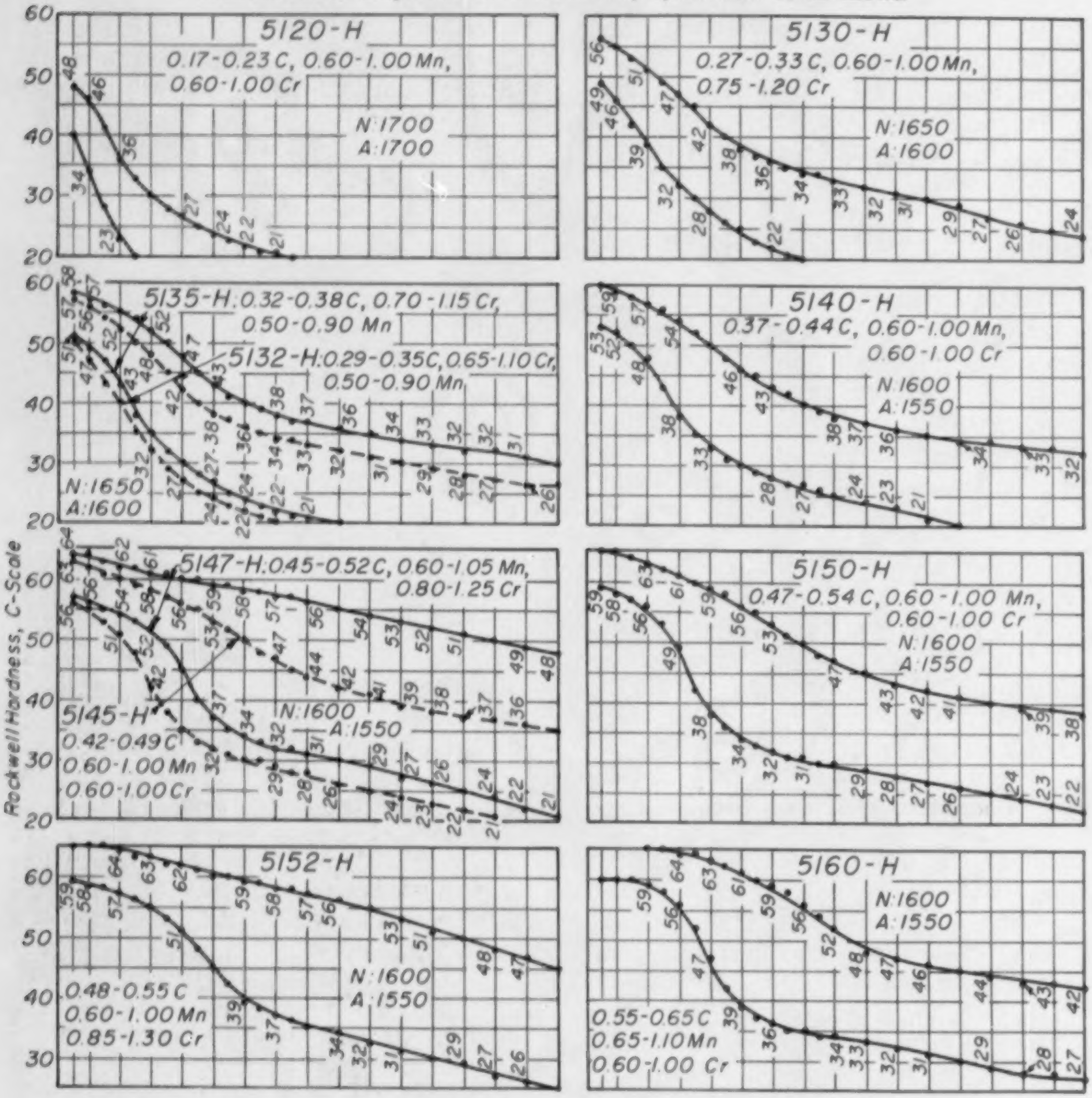
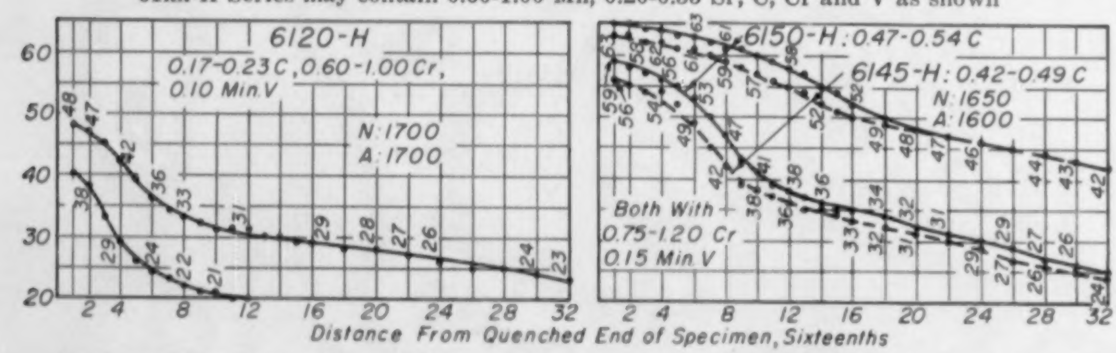
**THE INTERNATIONAL NICKEL COMPANY, INC.** 67 WALL STREET NEW YORK 5, N. Y.

# Standard H-Steels, 5120-H to 6150-H

51xx-H Series may contain 0.20-0.35 Si; C, Mn and Cr as shown




61xx-H Series may contain 0.60-1.00 Mn, 0.20-0.35 Si; C, Cr and V as shown




N means normalizing temperature for forged or rolled material; A means austenitizing temperature (both as recommended by S.A.E.).

Hardness limits are specified in Rockwell C-scale units (no fractions) and can be scaled from the plotted points where not labeled at even sixteenths.

A.I.S.I. list of February 1954.

# History of Gun Tubes Part III–Steel for Cannon

*By PETER R. KOSTING**

**The first two portions of this history of materials for large Army gun tubes were published in the May and June 1954 issues of *Metal Progress*. Part I covered the use of cast iron, while Part II traced the history of wrought iron and brass cannon. In this concluding part, the transition from cast iron to steel, which took place roughly between 1861 and 1888, is described, and the modern development of steel guns is reviewed.**

THE TRANSITION from cast iron to steel for large cannon took place in the period from about 1861 to 1888. The transition was complex, and involved two major programs authorized by Congress. More than 60 experimental weapons were made, ranging in size from 3-in. to 12-in. Some failed unexpectedly and others were deliberately fired to destruction. Several years frequently lapsed bewteen the decision to build a weapon and completion of the firing test. Progress was spasmodic.

The Ordnance Corps, after studying European developments, found that conditions in this country were limited by our industrial capacity to make large forgings. Specifications were that the weapons must be reliable, low in cost and capable of being made in quantity within the country. Many different expedients were therefore tried – wrapping thin tubes with small-diameter wire to make big guns, reinforcing the tube with many small hoops instead of a few large ones, and designing cumbersome breech-loaders incorporating many small steel forgings instead of the large forgings that were being used in European designs.

As early as the 1860's a Prussian manufacturer was using an all-steel construction for large cannon, and in England wrought iron was frequently used. The question of muzzle-loading or breech-loading weapons was finally resolved in 1879 in favor of the latter. Progressively burning propellant powder required longer tubes and this increased the difficulty of casting cannon. But not one of the European systems made cannon of the weight, power, and reliability demanded by the American Ordnance Corps.

### Steel Vs. Cast Iron

The arguments advanced in favor of steel included such advantages as forgeability, strength, ductility, and toughness. Against the use of steel was the old argument that since the gun was designed to resist plastic deformation, elastic limit was the important factor and there was no need for the ductility, toughness, or high tensile strength provided by expensive steel. Thick cast iron tubes should be used because weight was beneficial in recoil. To keep gases out of the heat cracks which formed on the bore, thin liners could be inserted. All these and other ideas were considered in promoting the use of cast iron.

The Ordnance Corps experimented with steel

*Metallurgist, Watertown Arsenal Laboratory, Watertown, Mass. Statements and opinions are to be understood as individual expressions of this author and not those of the Ordnance Corps, Department of the Army.

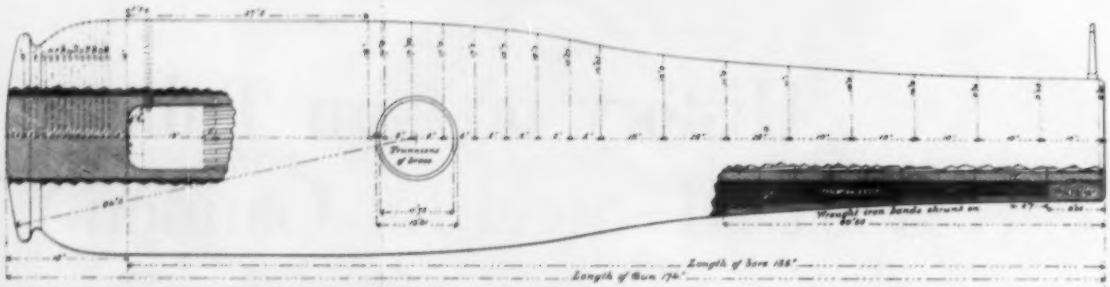


*Fig. 7 – Woodbridge Muzzle-Loading 10-In. Rifle; Gun A (1876)*. Rifled steel tube, 174 in. long, wire wound and brazed, steel collar at muzzle, nine wrought iron hoops, 5.7 in. wide, shrunk on at muzzle end, brass trunnions.*

**Table VI – Principal Types of Guns Tested During Transition Period; 1861-1888**

| Designation | Name or Type | Loading | Caliber | Characteristic |
|---|---|---|---|---|
| Gun A | Woodbridge | Muzzle | 10-in. | Wire-wrapped |
| B | Crozier | Breech | 10-in. | Wire-wrapped |
| C | Converted | Muzzle | 8-in. | Wrought iron tube |
| D | Converted | Muzzle | 8-in. | Steel tube |
| E | Converted | Breech | 8-in. | Steel jacket |
| F | Converted | Breech | 12-in. | Steel jacket |
| G | Field | Breech | 3.2-in. | All-steel, all-American |
| H | Experimental | Breech | 8-in. | All-steel |
| I | Converted | Muzzle | 8-in. | Steel tube |
| J | Watervliet Arsenal | Breech | 8-in. | All-steel, all-American |

at least as early as 1845, in the form of fine, cast steel rifled barrels for small arms. Among the advantages claimed over wrought iron were greater homogeneity, superior hardness and strength, better machinability, machined surfaces of smoother finish, fewer flaws, and a marked reduction in the number of rejections during manufacture. In 1848 the adoption of such barrels was recommended.

Extensive use of steel was proposed during the Civil War, but of 18 field guns submitted in 1861, seven failed to pass the proof test and one developed a defect later.

### The Program of 1872

After the Civil War the Ordnance Corps made plans to develop large guns for seacoast defense, but Congress did not authorize tests until June 6, 1872. Forty proposals, some from the Ordnance Corps itself, and others invited from inventors and manufacturers, were submited for review. Nine recommendations were made for manufacture and trial, each to be tested according to priority and the availability of funds. They included muzzle-loading and breech-loading weapons made of cast iron, wrought iron, and steel, either alone or in combination. In the following account, only the key weapons in the development of steel are mentioned. Many weapons of interest from the design standpoint are not discussed here.

**Wire-Wrapped Guns** – The first priority in the 1872 program was given to the Woodbridge muzzle-loading 10-in. rifle, shown in Fig. 7 and designated Gun A in Tables VI, VII, and VIII. This consisted of a thin steel rifled tube with 1½-in. wall, strengthened by wrapping with steel wire brazed to join the strands together and add to the longitudinal strength. Wrought iron bands, shrunk on, made up the outer surface. The steel tube was obtained from England in November 1872. The finished ube was 13 in. O.D., 10 in. I.D., and 174 in. long.

Dr. Woodbridge made an extensive study of the mechanical characteristics of available wire. Materials tried were designated as "crucible" steel, "Martin" steel, "chrome" steel, "Norway iron," "best cast steel" (worked down to rod size), "German" steel, "Bessemer" steel, "Prussian" steel. To minimize variations due to differences in drawing, all samples were uniformly

* All illustrations are from photographs from "Annual Report, Chief of Ordnance" for the year noted in parentheses. Figure and table numbers are continued from the previous installment of this history, carried in the June 1954 issue, p. 91.

**Table VII – Materials and Firing Tests for Guns in Table VI**

| Gun | Material* | | | | Authorized | Tested | Approved | Remarks |
|---|---|---|---|---|---|---|---|---|
| | Casing | Tube | Jacket | Hoop or Wire | | | | |
| A | — | Steel *(a)* | W.I. | Steel wire *(d)* | 1872 | 1874; 1881 | — | Failed at excess pressure; satisfactory. |
| B | — | Steel *(b)* | Forged steel | 0.1-in. square steel wire *(a)* | 1888 | 1894 | 1896 | Eroded after 275 rounds; satisfactory |
| C | C.I. | W.I. *(a)* | W.I. *(a)* | — | 1872 | 1874 | 1874 | Conversion technique approved |
| D | C.I. | Steel *(c)* | Steel *(c)* | — | 1872 | 1874 | — | Tube failed after 456 rounds; steel unsatisfactory |
| E | C.I. | W.I. | Steel *(a)* | Steel *(a)* | 1876 | 1878 | 1880 | Mechanical properties of steel (Table VIII) adopted as standard for guns |
| F | C.I. | W.I. | Steel *(a)* | Steel *(a)* | 1880 | — | — | Not completed; jackets rejected (1881) |
| G | — | Steel | Steel | Steel (casting) | 1882 | 1884 | 1885 | American openhearth steel selected |
| H | — | Steel *(a)* | Steel *(a)* | Steel *(a)* | 1883 | 1886 | 1889 | Steel forgings for smaller hoops procured from Midvale Co. in U.S. |
| I | C.I. | Steel | — | — | 1883 | 1884 | 1884 | Steel cheaper than wrought iron |
| J | — | Steel | Steel | Steel | 1885 | 1889-1894 | 1889 | First 8-in. gun made entirely from American steel |

*Unless otherwise noted, materials were made in America; C.I. stands for cast iron, W.I. for wrought iron.
*(a)* From England *(b)* From France *(c)* From Germany *(d)* Wrought iron hoops

annealed at a bright red heat, removed from the furnace and cooled in powdered lime. Since the "skillful workman sometimes failed to judge correctly of the heat, a means of greater certainty was soon employed". Little tubes were made by drilling the gun wire, and were filled with pieces of metal of different fusion points. The "standard of heat" adopted was between the melting points of copper and an alloy of five parts of copper to one of tin. Only samples annealed at this standard temperature were tested. Compositions of only a few samples were given–sulphur up to 0.045%, phosphorus up to 0.137%, carbon from 0.399 to 0.720%, silicon 0.019 to 0.154%, and manganese 0.323 to 0.847%. "An unexpected degree of extensibility" of the specimens was observed in special tests in which the wire was strained by the explosion of gunpowder, and in general, "the most excellent specimens were of American production."

Many difficulties were encountered during manufacture of this Woodbridge gun. While brazing, an accident occurred and the operation was finished by substituting tin for bronze. The gun was completed by 1876 and was fired 10 rounds. In 1881 the gun was fired using excess-pressure rounds, and a crack on the exterior surface near the trunions was observed by the 65th round. It grew only 0.01 in. from the 65th to 85th round. The gun blew up on the 93rd round under a powder pressure of 80,000 psi. The strength and behavior of this weapon, even though cracked, formed the basis for further experimental studies of wire-wound cannon.

Another reason for the interest in wire-wrapped guns was that in the process of making the wire the steel was subjected to stresses greater than it would normally encounter in service. Defects such as cracks and slivers could be detected and eliminated, and the metal was considered to be extremely reliable.

After three other wire-wound guns were tested, the Crozier 10-in. breech-loading gun (Gun B in Tables VI, VII, and VIII) was authorized in 1888. This was wire-wound on a steel tube with 4½-in. wall – much thicker than the Woodbridge gun (A) described above – and with a steel jacket over the wire instead of

wrought iron hoops. In the winding an innovation was the substitution of welding for splicing and soldering of one strand to the next as winding progressed. After several cast steel jackets for the weapon were rejected, a forging was substituted, using steel from France. The gun was fired 275 rounds and withstood pressures as high as 46,000 psi. The firing test was ended because of erosion.

In the period up to and beyond World War I larger wire-wound seacoast cannon were introduced at a cost about 25% less than that of equivalent built-up guns. Large cannon have not been wire-wrapped since about 1922, although wire-wrapping of small tubes was used during World War II.

**The wrought iron gun** had second priority in the 1872 program, but the inventor abandoned the experiment in 1875 and the gun was never built. (See *Metal Progress* for June 1954, p. 92).

**The Lined Cast Iron Gun** – The third priority in the 1872 program was the recommendation of the Ordnance Corps to convert cast iron smooth-bore guns into lined rifles, as an economical means of modernizing more than 1700 Rodman guns of the Civil War period. The method was based on European practice. Four 10-in. cast iron weapons were selected for the initial experiment. Two were converted to 8-in. rifles, one by inserting a jacketed wrought iron tube from the muzzle end, and the other by inserting a jacketed steel tube from the breech end. The remaining two were converted to 9-in. rifles in similar fashion. The tubes for the liners were obtained from Europe because they were larger than those which American industry could supply at the time. American manufacture of these large tubes did not commence until later, as will be observed further on.

As noted above, the first of these experimental 8-in. weapons (Gun C in the tables) had a jacketed wrought iron tube inserted through the muzzle end. The jacket was also of wrought iron and was shrunk on. The gun was completed by October 1874, tested for endurance and found to be satisfactory. It was lighter in weight and just as powerful as matching European guns.

The second weapon, shown in Fig. 8 and listed as Gun D, was a companion to the first, but had a steel-jacketed steel tube inserted from the breech end of a re-bored Rodman gun. The steel tube was obtained from Germany. On the 175th test round a crack was detected in the steel, and on the 456th round the tube failed. In a study of the cause of failure it was concluded that the steel was too hard, and wrought iron was selected as the preferred material for these liners.

The two 9-in. weapons in this program were built and fired but were not considered satisfactory in ballistic performance.

**Table VIII – Mechanical Properties of Steel in Guns Listed in Table VI**

| Component | Tensile Strength* | Elastic Limit* | Elongation* | Reduction of Area* |
|---|---|---|---|---|
| Gun A; tube | † | 27,000 psi. | 20% | — |
| Gun B; tube, bore | 85,200 (T) | 37,500 (T) | 20 | 47% |
| Mid wall | 82,000 (T) | 37,500 (T) | 22 (T) | 50 (T) |
| Wire, 0.1 in. square | 172,000 (L) | 142,000 (L) | 1.8 (L) | 38.6 (L) |
| Gun D; tube | † | — | — | 25.4 (L) |
| Jacket | † | — | — | — |
| Gun E; sample | 86,000† | 38,500 | 17.5 | — |
| Jacket | 83,500 | 32,500 | 20.5 | 43.1 |
| Gun F; jacket (rejected) | 60,500† | 16,300 | 15.6 | — |
| Gun G; tube | 87,700 (T) | — | 16 (T) | 20 (T) |
| Jacket | 102,900 (T) | — | 14.5 (T) | 22 (T) |
| Trunnion hoop | 96,700 | — | 19.5 | 40 |
| Gun H; tube | 98,800 (T) | 51,500 (T) | 17.8 (T) | 40.5 (T) |
| Jacket | 94,100 (L) | 53,000 (L) | 23 (L) | 51.3 (L) |
| | 93,800 (T) | 52,500 (T) | 21 (T) | 39.2 (T) |
| Trunnion hoop | 86,700 (T) | 36,300 (T) | 17.4 (T) | 50.5 (T) |
| Gun I; tube | 79,400 (T) | 37,000 (T) | 22.6 (T) | 30.2 (T) |
| Gun J; tube (breech end) | 86,200 (T) | 46,000 (T) | 21.0 (T) | 52.2 (T) |
| Tube (muzzle end) | 91,600 (T) | 50,000 (T) | 21.3 (T) | 41.9 (T) |
| Jacket (breech end) | 94,000 (T) | 46,000 (T) | 17 (T) | 33 (T) |
| Jacket (muzzle end) | 94,000 (T) | 47,000 (T) | 18 (T) | 32 (T) |
| Trunnion hoop | 107,700 (T) | 57,000 (T) | 13.8 (T) | 38.8 (T) |

*T stands for tangential; L for longitudinal. Size of specimens was not uniform in all tests.

†Some early mechanical property tests included a figure for "tenacity", defined as "the stress calculated on the basis of the cross-sectional area of the smallest part of the specimen, after necking, to carry the load required to cause breaking". Unfortunately, tenacity was sometimes calculated by the same method as tensile strength—namely, "the stress, calculated on the basis of the original cross-sectional area of the specimen, required to cause breaking." Values for tenacity were as follows: Gun A, 67,000 psi.; Gun D, tube, 88,000; Gun D, jacket, 90,100; Gun E, 110,000; Gun F, 78,300.

**Steel Jackets** – In the 1872 program the fourth priority was to be an investigation of the Prussian system of breech-loading guns, but satisfactory contracts for this work could not be negotiated. However, as the rifle conversion program developed, the next obvious step was to prolong the jacket to the rear and adapt it for the breech block. This was done in an experimental 8-in. weapon, which was first considered in 1876, finished and proofed in 1878, and tested by 1880, after which this mode of construction was approved for service weapons.

This rifle (Gun E) had a cast iron casing (C of Fig. 9), a loose-fitting wrought iron tube A, a steel jacket B shrunk onto the breech end of the tube, and a narrow steel breech band D shrunk over the *outside* of the casing. The jacket forging B was obtained from Sir Joseph Whitworth and Co. in England, and was probably of an intermediate carbon steel. The company had an excellent reputation and manufactured "fluid compressed steel."* The forging was rough bored and turned, then quenched in rape oil and tempered (in the language of the time, "tempered in oil" and then "annealed"). Compared to "untempered" steel, the hardness, tensile strength, and particularly the elastic limit were raised, but with a slight sacrifice in ductility. Specimens taken from the ends of each forging were used to determine the required temperature for "oil tempering". Mechanical property specifications were based on a large steel test block obtained from England. Results for both the test block and the forging for Gun E are listed in Table VIII; they formed the basis of the steel specifications for the first production order for 8-in. guns as well as for other later guns.

In the construction of this gun, the cast iron casing was heated to 633° F. The jacketed liner was filled with cold water and inserted into the hot casing until the threads at the muzzle came into contact, when it was rapidly screwed tight. This operation required 8 min.

Temperature measurement, by a "hydro-pyrometer", was ingenious but time-consuming. A copper ball inside a cast iron cage was placed in the bore of the casing during heating, then withdrawn and plunged into a water calorimeter. From the temperature rise of the water, the temperature of the ball (and thus of the casing) could be calculated. In the meantime the coal fires under the furnace were kept burning at a uniform rate in order to maintain the temperature of the casing. For measuring temperatures during shrinking and assembling, special long-stem mercury thermometers were used, but were soon broken in the shops. Another method of measuring temperature was based on the time required for a 1-in.cube of fusible metal such as lead and tin to melt when placed in a cavity in a forging. The rate of burning of coal or wood fires was then adjusted to change the temperature as desired. In the middle 1880's the color change of freshly machined steel surfaces was used to judge the temperature history of the piece. Color of the forging in the heat treating furnace was used as a temperature indication, "low cherry heat", "high cherry heat" and "yellow heat" being common terms used in tempering, oil quenching, and annealing.

Gun E performed satisfactorily, and in 1880 an order was placed for five more 8-in. breech-loading rifles, and development work was started

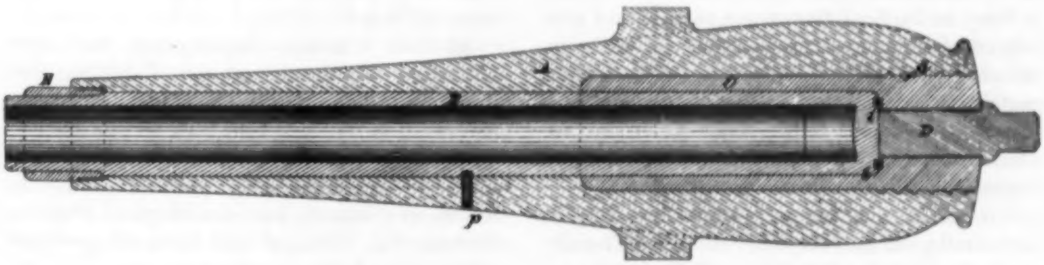



*Fig. 8 – Gun D, 8-In. Muzzle-Loading Rifle With Breech-Inserted Steel-Jacketed Steel Tube (1876). (A) Casing; (B) steel tube; (C) steel jacket; (D) plug; (E) steel collar; (p) steel pin*

*According to Tiemann's "Iron and Steel", in the Whitworth process the steel was cast in a cylindrical mold with vertical walls, and a hydraulic plunger forced down on top of the molten ingot, the purpose being to eliminate blowholes and central pipe.

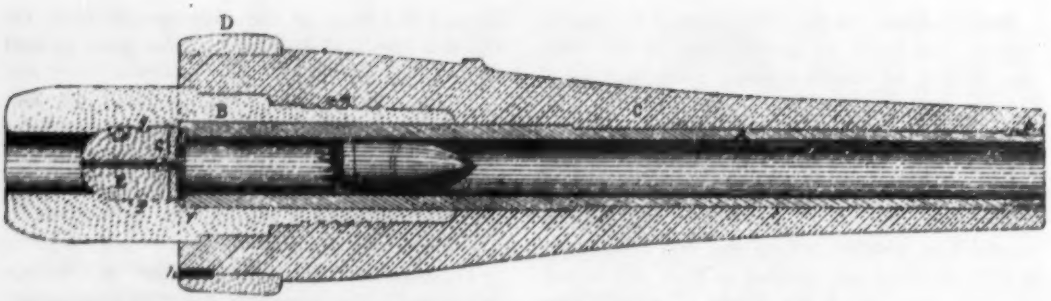


*Fig. 9 – Gun E (1878), 10-In. Rodman Smooth-Bore Converted to 8-In. Breech-Loading Rifle by Lining With a Wrought Iron Tube, Steel-Jacketed, Inserted From the Breech. Jacket was prolonged to rear and adapted to receive the breech block. (A) Wrought iron tube; (B) steel jacket; (C) cast iron casing; (D) steel breech band; (E) steel breech block*

on 11-in. and 12-in. weapons of the same design. The steel forgings were again obtained from England but from a different company. In the winter of 1881 one 8-in. weapon and one 11-in. weapon unexpectedly failed at proof by fracture of the steel jacket. The consequence was not only a delay in the final acceptance of steel and a renewed effort to use cast iron, but also a recommendation that the quality of American steel suitable for cannon be evaluated in the United States Government testing machine. (The machine had a capacity of 800,000 lb., and had been installed in 1879 at Watertown Arsenal.)

Growth of American forging facilities may be estimated from the fact that West Point Foundry made the "coiled welded" wrought iron tubes for these 8-in. converted guns, the earliest in 1875, whose dimensions ranged up to 13.5 in. outside diameter and 123.3 in. long.

Unexpected failure of one of the 8-in. rifles was judged to be caused by poor design as well as by poor steel. The fracture occurred at the recess for the breech block; there was no fillet at the corner, as there had been in Gun E, Fig. 9. Therefore, the next rifle was altered by undercutting and rounding the troublesome corners with a generous fillet. This was fired to destruction at excess pressures; steel jacket, wrought iron tube, cast iron casing, and steel breech band all fractured on the 127th round, indicating uniform strength of all parts. The design was now considered to be satisfactory.

Nevertheless, the English steel from the various weapons was found to break with a brittle "crystalline" fracture when hit with a sledge hammer. Strength was low (see Gun F in the tables) and sulphur and phosphorus were high (0.247% and 0.095%, respectively). In addition, the steel company had refused to oil quench the forgings for the 11 and 12-in. guns because of danger of cracking. These large forgings were rejected and the importance of strength of the steel to the design of the gun was recognized. No longer were large forgings accepted just because they were delivered.

**All-Steel Cannon** – Experiments had been started in 1878 to convert muzzle-loading 3-in. field guns to breech loaders. A steel breech receiver 6.2 in. O.D., 3.2 in. I.D., and 25 in. long was screwed onto an old wrought iron muzzle loader. The steel forging was fairly large by American standards and was obtained from the Midvale Co. The steel had been oil quenched and tempered. The weapon was successful.

Several other weapons were altered and fired in order to test different design features. In 1882, the Ordnance Corps sponsored an all-steel breech-loading 3.2-in. field gun to be manufactured of domestic steel (Gun G). The tube forging was to be 6 in. in diameter by 85.2 in. long; the jacket 9.56 in. O.D., 5.89 in. I.D. and 27.15 in. long; the trunion band 14.2 in. O.D., 5.6 in. I.D., and 8.80 in. long. The tube was to be annealed, and the jacket and trunnion band were to be oil quenched.

To select the material for this gun a circular letter was sent to several steel manufacturers, and two favorable plants were inspected, one of which made openhearth and the other bessemer steel. The openhearth forgings seemed to be of better quality and the Midvale Steel Co. was awarded the contract. Facilities for machining the forgings were not ready until Jan. 8, 1884. The completed gun performed successfully in the firing tests and this mode of construction was approved in 1885 and production started.

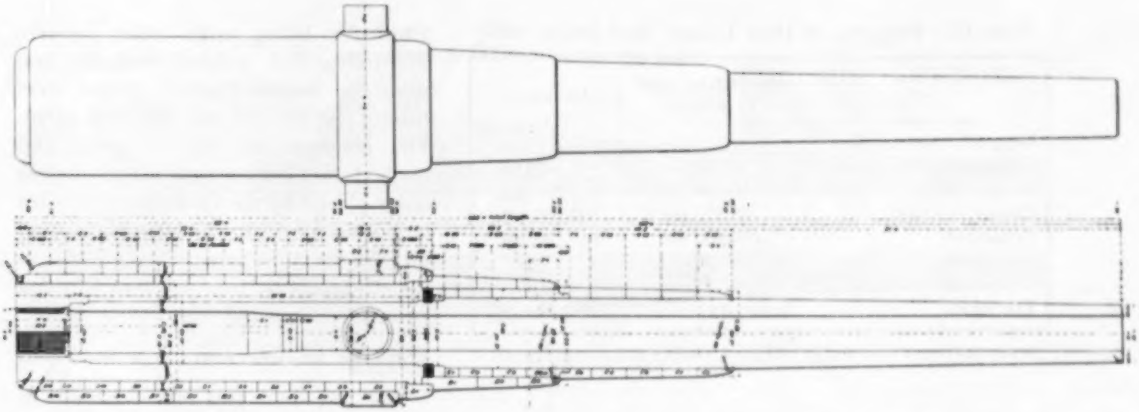


*Fig. 10 – Gun H, Experimental All-Steel 8-In. Breech-Loading Rifle (1886). Steel tube, jacket and trunnion hoop obtained from England; all other hoops from Midvale Steel Works, U.S.A.*

### The Program of 1883

The aftermath of the 1881 failures of seacoast guns included studies by several boards. Plans were laid for experimenting with several types of guns, including cast iron weapons wrapped with wire, cast iron hooped with steel, cast iron tubed and hooped with steel, steel weapons wrapped with wire, and steel hooped with steel. The program of 1883 was approved by Congress and work was started immediately.

In this program an experimental 8-in. breech-loading rifle (Gun H; Fig. 10) was designed by the Ordnance Corps to use small steel forgings in order that as many as possible could be obtained from domestic sources. The large forgings for tube, breech jacket and trunnion hoop were ordered from Whitworth in England. Their dimensions were: tube, 14.05 in. O.D., 8 in. I.D., 245.7 in. long; jacket, 23.3 in. O.D., 11 in. I.D., and 99.9 in. long; trunnion hoop, 46 in. O.D., 26.3 in. I.D. and 13.5 in. long. A preliminary order for three experimental trunnion hoops and the main order for the smaller forgings (12 inner hoops and ten outer hoops over the reinforce of the gun, and nine inner hoops and three outer hoops over the rear portion of the chase) were placed with Midvale in America. The contract for fabrication of the gun was placed with Messrs. Paulding, Kemble & Co., West Point Foundry, Cold Spring, N.Y., in June 1884. The first shipment of foreign forgings was rejected because of low strength and irregular quality, but was replaced by acceptable forgings with properties as shown in Table VIII, lines for Gun H. After much experimentation the gun was finally completed and proofed in 1886. Trouble was encountered in the procurement of suitable propellant powder, and not until 1889 was the endurance test of 300 rounds finally completed.

**Heat Treating Test Programs** – European heat treatment of large gun forgings followed one of three principal procedures: *(a)* annealing, boring, oil quenching and tempering; *(b)* annealing, boring, and oil quenching; and *(c)* very slow cooling. The first procedure seems to have been preferred but in 1882 the question was formally raised whether or not quenching and tempering were really necessary. In 1883 tests to resolve this doubt were carried out in this country in connection with the concurrent development of a 12-in. cast iron mortar reinforced with steel hoops. Two of the experimental hoops from Midvale, each 45.5 in. I.D., 53.5 in. O.D., 4 in. thick, and 5.6 in. wide, were shrunk on cast iron cylinders. One hoop was simply annealed; the other was oil quenched and tempered. Comparisons of the mechanical properties of the steel are given in Table IX. The quenched and tempered hoop machined easily and uniformly but the annealed hoop had hard spots. The former also showed higher resistance to permanent deformation in shrink tests. The controversy seemed therefore to be settled in favor of using quenched and tempered steel. Yet the quenched and tempered steel yielded nonuniformly. Manufacture of the 12-in. mortar was held up while this was investigated. When it was found that the hoop was nonuniformly heated during tempering, the condition was rectified by installing a new furnace.

Many similar experiments were carried out to evaluate theories for the calculation of shrinkage and to obtain additional information on factors that affect steel quality. In 1885 tests were made by assembling and dismantling a compound cylinder made of a steel tube with a steel jacket

**Table IX – Properties of Heat Treated Steel Hoops, 1883**

| | Quenched and Tempered | Annealed |
|---|---|---|
| Length of test section | 3 in. | 3 in. |
| Diameter of test section | 0.5605 in. | 0.5623 in. |
| Elastic limit | 56,250 psi. | 46,250 psi. |
| Tensile strength | 99,250 psi. | 102,500 psi. |
| Tenacity* | 188,400 psi. | 135,100 psi. |
| Elongation | 19.3% | 17.9% |
| Contraction of Area | 47.3% | 24.1% |
| Fractures | Some crystalline† | All crystalline |

*See footnote † to Table VIII. †Some silky and fibrous

and double hoops, simulating the 8-in. all-steel gun. Clavarino's formula for shrinkage, except for the consideration of longitudinal stresses, was verified. The effect of the heating during the shrinkage operation upon the tensile properties of the steel was determined. A means of heating without damaging a hoop of oil tempered steel was worked out by pouring molten cast iron around it; the purpose was to heat the hoops uniformly for assembling and even dismantling. Such engineering tests were to continue up to present times.

**Muzzle-Inserted Steel Tubes** – The next experimental weapon made possible by the enlargement of forging facilities is the 8-in. muzzle-loading rifle converted from a 10-in. smooth-bore Rodman gun by lining with a muzzle-inserted steel tube (Gun I). Its purpose was threefold– *(a)* to simplify the conversion of smooth-bore cannon into rifles; *(b)* to substitute steel for wrought iron; and *(c)* to lower the cost of manufacture. In 1884 an annealed solid forging of openhearth steel, 126.75 in. long and 14.5 in. in diameter, was obtained from the Midvale Co. –really a very large one–and made into a tube with an outside diameter of 12.994 in. This was fitted loosely into a casing with a diameter of 12.999 in. – a clearance of 0.005 in. Since experience in 1876 indicated that ductility should be maintained at a sacrifice of strength, the forging was annealed. Chemical composition of the metal was 0.39% C, 0.90% Mn, 0.15% Si, 0.021% S, 0.026% P, and mechanical properties were:

| Properties | Specified | Tested |
|---|---|---|
| Elastic limit | 28,000 psi. | 37,000 |
| Tensile strength | 70,000 | 79,000 |
| Elongation | 20% | 23 |
| Reduction in area | – | 30 |

The gun (Fig. 11) was successfully fired 500 rounds in 1884 and this alternate method of manufacture was approved. Bids were therefore invited for lining with either breech-inserted coiled welded wrought iron tubes or muzzle-inserted forged steel tubes. The low bid was for steel tubes. The contract was for 50 guns, and marked the first successful production order placed by the Ordnance Corps for large steel forgings. The program, started in 1872 for the conversion of Rodman smooth-bore cast iron weapons to rifled guns was completed with this order.

### The First All-American Large Steel Gun

The first 8-in. gun made entirely of American steel was the 67th gun in the series started in 1872; it is listed as Gun J in the tables. As previously mentioned, delivery from England of satisfactory large forgings for the first all-steel rifle had been slow, and encouraged by the expansion of domestic forging and heat treating facilities, the Ordnance Dept. placed a contract with Midvale in April 1885 to make forgings for the tube, jacket and trunnion hoop for an 8-in. gun. If these forgings should be satisfactory, the hoops for the gun would also be ordered. These were the largest gun forgings yet attempted in this country.*

The tube forging was rough turned and bored, and then heat treated. It warped badly, but the Ordnance Corps inspectors judged that there was sufficient metal for machining satisfactorily. Two forgings, one for an experimental trunnion hoop and a hoop for the gun itself, were accepted by 1886. The jacket also caused difficulty. Altogether five forgings were prepared and the fifth was heat treated three times before it was accepted in 1887. The gun was manufactured at Watervliet Arsenal, where a complete plant had to be installed and tooled. Work on the gun was started on March 12, 1888, and completed on Aug. 26, 1889. The first firings, in December 1889, were made to evaluate the propellant powder. By October 1890 the gun had been fired 76 rounds, and by 1894 it had completed the endurance test.

Sizes of the forgings differed somewhat from those of the first all-steel gun. A thicker jacket was used, eliminating the row of outer hoops over the reinforce. Forgings used in production orders which followed the success of this gun

*Dimensions of tube were 15 in. max. O.D., 8.0 in. I.D., 261.5 in. long; jacket dimensions were 24.5 in. max. O.D., 15 in. I.D., 109.1 in. long; trunion hoop dimensions were 46 in. max. O.D., 23.5 in. I.D., 13.5 in. long.

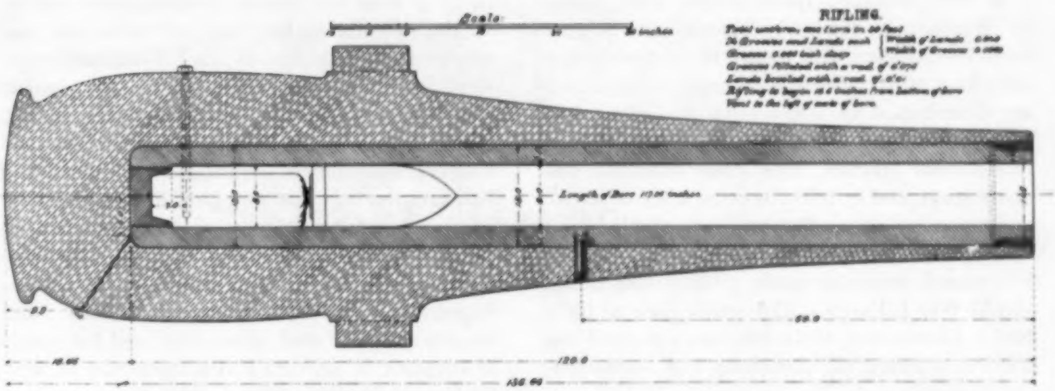



*Fig. 11 – 8-In. Muzzle-Loading Converted Cast Iron Rifle With Muzzle-Inserted Steel Lining (1883). Steel tube 126.75 in. long made, forged and heat treated at Midvale*

analyzed 0.25% C, 0.65% Mn, 0.15% Si, 0.25% S, and 0.25% P.

On March 20, 1888, in his letter to the Secretary of War, Brigadier General S. V. Benet, Chief of Ordnance, wrote that cast iron was not strong enough nor reliable enough for rifled mortars; that the cast iron breech-loading rifles were showing poor resistance to erosion; that the 8-in. breech-loading rifle made of steel was superior to the cast iron weapons; that the placing of a contract by the Navy Department with the Bethlehem Steel Works assured a suitable plant for steel forgings for guns bigger than 8-in., and that this plant would begin delivering gun forgings by May 1, 1889. The following is quoted from his letter: "The true policy now to pursue is the manufacture of all-steel guns."

This is considered to mark the end of the transition from cast iron to steel for cannon, and the initiation of manufacture of high-power seacoast guns of steel.

### The Steel Era

In the 1880's the engineering and the metallurgical aspects of cannon began to be handled by separate groups of investigators. The first all-steel built-up 8-in. seacoast gun was followed in quick succession by 10, 12, and 16-in. weapons. The wire-wound gun and mono-block construction (investigated in 1899) assured alternate methods of manufacture. In 1920, Gen. Tracy C. Dickson developed the process of autofrettage or self-hooping by cold working. The centrifugally cast gun tube (initiated in 1918 and followed by experimental work in 1925) was limited to smaller weapons than the cannon discussed in this history. Attempts to use cast steel tubes for large seacoast guns date as early as 1884, but were not successful.

Quality requirements of steels for tubes remained high. The 1883 specifications were based on European practice, and required openhearth or Siemens-Martin steel. The ingot was to weigh about 2½ times as much as the finished solid forging, and ingot diameter to be at least twice that of the finished forging. The forging was to be free of soft and hard spots. If "low" steel was used, heat treatment was required. After hot working, the metal was annealed and specimens taken for preliminary examination. If satisfactory, the forging was rough bored and turned, quenched in oil and tempered. Mechanical property specifications were: Elastic limit, 42,300 psi.; tensile strength, 87,500 psi.; elongation, 18%. In 1885, these figures were changed to 48,000, 90,000, and 21, respectively. The specifications required much less ductility in components which were less highly stressed than the gun tubes, but this distinction ceased as soon as the steel industry demonstrated it was unnecessary. (Some of the components failed in service unexpectedly, indicating the necessity for high-quality steel for all gun parts.)

**Alloy steels** came into use in 1892 when nickel steel was considered for small arms; in 1893 nickel steel was specified for a tube forging supplied by the Bethlehem Iron Co. for a 12-in. gun. Steels for cannon were then specified as either "gun steel", which was the customary carbon steel, or "alloy steel". While chemical compositions were never specified, the first alloy steels usually contained 3 to 3.5% nickel. "Alloy steel" gave about 10,000 psi. better elastic strength than "gun steel" with the same ductility.

In 1897 metallographic studies were started at Wartertown Arsenal. "Streaks" in forgings were investigated with regard to *(a)* their origin; *(b)* effect on transverse weakness; *(c)* change in the distribution of nonmetallic inclusions from ingot to finished forging; and *(d)* influence of deoxidation practice. This study extended over many years, and in 1909 the occurrence of streaks and open cracks or fissures was established in forgings which failed in service.

Research programs made great strides during World War I. Various alloy steels, such as Cr-V, Ni-Cr, Cr-Mo, and Ni-Cr-Mo, were studied, and water quenching, oil quenching and normalizing were investigated.

Although the Ordnance Corps was interested in impact testing of nonferrous metals as early as 1880, it was not until 1913 that impact testing of steel for cannon was initiated. One of the first Charpy machines in this country (if not the first) was installed at Watertown Arsenal. Tests on the steel jacket of a large gun immediately demonstrated that impact resistance was more sensitive than ductility and other mechanical properties for revealing differences due to heat treatment. In 1921 F. C. Langenberg received a Carnegie Scholarship Award of £100 to carry out research on impact testing at Watertown Arsenal, and he studied the keyhole Charpy impact resistance of steel in the temperature range –80 to 1000° F. Tensile impact testing was also developed at this time, using specimens similar to notched and unnotched tensile specimens. By 1922 it could be reported that the steel components of guns which ruptured unexpectedly had low impact resistance, especially when notched, and impact testing was introduced into specifications for cannon forgings in 1929. (Although the metallurgical use of the Charpy test was recognized, its engineering use was not, and the impact test was dropped temporarily from specifications for gun steels in 1940.)

In addition to the keyhole Charpy specimen, extensive use was made of the tensile impact specimen with a test section 0.05 in. long. In 1936 H. C. Mann of Watertown Arsenal was awarded the Charles B. Dudley Medal of the American Society for Testing Materials for his work on the influence of velocity of test upon tensile impact resistance.

In 1943 troubles with highly stressed field guns were encountered during endurance testing. Under the technical guidance of Col. H. H. Zornig metallurgical research was coordinated, resulting in a better understanding of the metallurgy of steel for cannon. Included were studies of the correlation between microstructure and mechanical properties of steel, hardenability of steel, heat treatment of steel tubes, the impact test, temper brittleness, low-temperature embrittlement, fracture, progressive stress damage and fatigue, influence of strain rate on yield and fracture, the equivalence of strain rate and temperature, statistical study of the strength and fatigue characteristics of gun forgings, band pressure, and strains in steel cylinders. The interdependence of yield strength, ductility, and toughness of the steel, stress level, and frequency of stressing, strain rate and temperature of service became apparent in a quantitative manner.

In 1943 the impact test was reinserted into specifications for steel for highly stressed weapons, a V-notch being used in the Charpy specimen. Later the specifications again were changed. The impact test was required for all steel for cannon, and the temperature of impact testing was lowered from room temperature to –40° F. for low-temperature service.

From time to time attempts have been made to use low-cost steel for cannon instead of high-priced forgings. In 1912 hot rolled bars were tried but the experiment was a failure. Seamless tubes for cannon were considered by the staff at Watervliet Arsenal as early as 1926, and were eventually developed to meet tremendous production schedules for field guns during World War II. Large cannon, however, still require quality forgings.

The composition of gun forgings is still not specified. The metal must be uniform, have specific mechanical properties, and be free from defects such as cracks. Carbon, molybdenum-vanadium, and nickel-chromium-molybdenum-vanadium are among the steels used for tubes for large cannon. Hardening by water quenching is frequently used.

As guns are fired faster and more often, they are subjected to intense heat. The strength of steel at higher and higher temperatures and after cooling down from these temperatures is important. The first study at Watertown Arsenal of elevated-temperature properties was made in 1890, and such studies are still continuing.

The present trend is to stronger and stronger steels for guns. Concurrent problems include attainment of high strength and toughness, machinability, residual stresses, saving of scarce alloys, and improved resistance to erosion. The work of the ordnance metallurgist never ceases.

*(Sources of information listed on p. 134)*

# Short Runs...

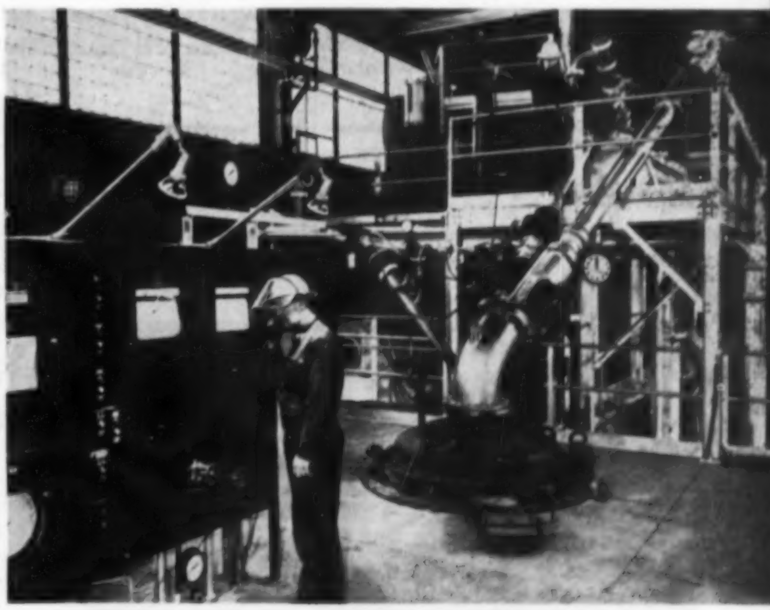
## Titanium

THE COMMERCIAL production of titanium by a method other than the Kroll Process will be used for the first time when the Electro Metallurgical Co., Div. of Union Carbide and Carbon Corp., completes the plant being built in Ashtabula, Ohio. According to an announcement by A. L. Foscue, president of the company, the $31 million plant will be in operation in about a year and a half.

The Electromet process involves sodium reduction of titanium tetrachloride, which produces metal of exceptional quality. The company has had this process in operation on a pilot and prototype-plant scale at its Metals Research Laboratories in Niagara Falls, N.Y. Almost $2 million has been spent during the past five years on research and development of this new process. A. B. Kinzel, research director of Union Carbide, has been in charge of this research program.

Although the primary market for titanium metal at the present time is in jet planes and other aircraft applications (under the terms of a contract between the company and the Government, the General Services Administration will purchase from Union Carbide, for a five-year period at prevailing market prices, that part of the plant's output not sold to private industry), the metal has interesting possibilities in other commercial fields. Because of its favorable strength-to-weight ratio the metal should prove to be particularly useful wherever there are metal parts in motion – for example, axial-flow compressors and reciprocating parts of various types of machinery.

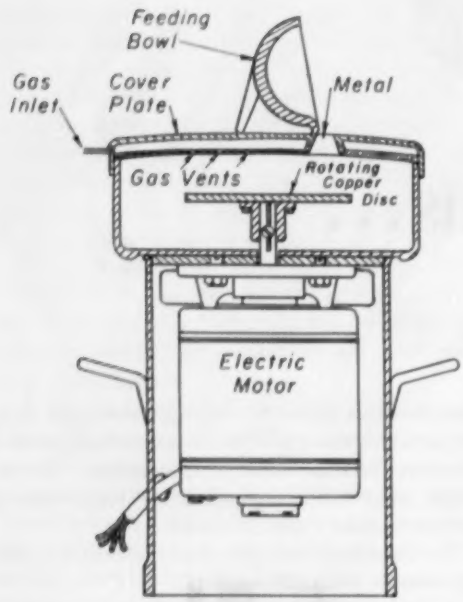
The chemical and petroleum industries also offer sizable potential markets.



*Pilot-Plant Operation of the New Titanium Process at the Metals Research Laboratories of Union Carbide and Carbon Corp.*

## Sampling

Furnace samples of steel or other metals are being produced in finely granulated or divided form directly from the molten state with the use of a rotary metal sampling machine that recently became available in England. The device, shown




*Rotary Metal Sampling Machine (16 In. High, 9 In. Diameter) Produces Finely Divided Particles From Samples of Molten Metal*

in the sketch, has a rotating copper disk which receives the molten sample and centrifugally disperses it upon the surface of a surrounding metal bowl. Oxidation during the sampling operation is prevented by providing a nitrogen or inert gas atmosphere in the dispersion cavity of the machine.

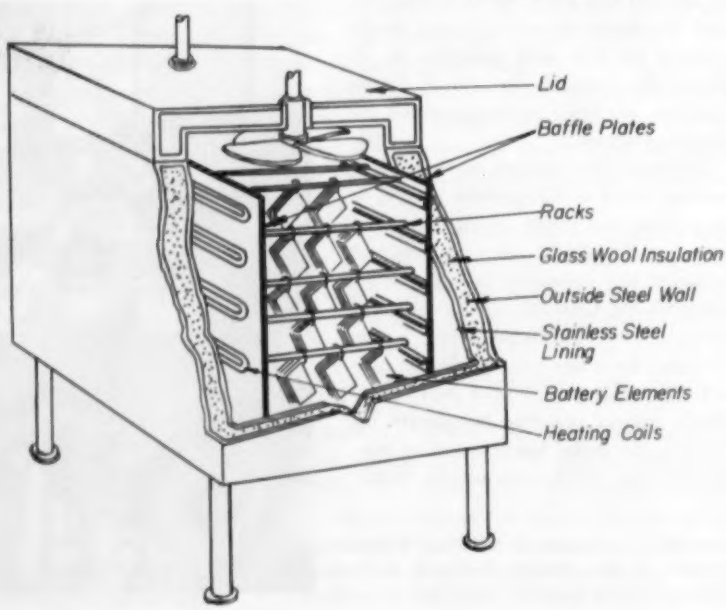
Results of extensive trials with this sampling device have revealed a high degree of reliability and correlation with analyses performed upon orthodox drilled samples, not only in respect to the normal elements (carbon, sulphur, silicon, phosphorus and manganese), but also in respect to nickel, chromium, molybdenum and tungsten. These trials were conducted by the British Steel Castings Research Assoc. in conjunction with the manufacturer of the equipment, Westberg Developments Ltd., Rotherham, England.

## Corrosion

Carl G. Reetz, director of engineering and production, Reading Batteries, Inc., had some severe corrosion to contend with in the drying of battery plates for dry charging. The plates, after being washed of the sulphuric acid electrolyte, are dried in heated cabinets (see below). As the drying progresses, water is first driven off and the sulphuric acid is left on the surfaces in a thin film of concentrate that vaporizes when the drying temperature reaches 400 to 500° F. The heated acid fumes and a certain residue of liquid acid, together with the temperature cycles, caused severe corrosion of the stainless steel used as lining in the cabinets.

The original liners were Type 302 stainless. In addition to the severe over-all attack, acid dripping on the bottoms of the cabinets ate holes in the steel next to the welded joints in about a week. After other corrective steps had failed, a lining of Carpenter Steel Co.'s stainless No. 20, which is resistant to sulphuric acid, was tried. This steel (0.07% C, 18% Cr, 29% Ni, 3% Cu, 2% Mo) is still in excellent condition after six years of service in the plant.

*Cabinet Used By Reading Batteries, Inc., for Drying Battery Plates. Problem was to find a steel for the lining that would resist corrosion by sulphuric acid*



# Personal Mention

**Robert H. Aborn**

**W. S. Pellini**

ROBERT H. ABORN, assistant director of United States Steel Corp. Fundamental Research Laboratory, Kearny, N.J., since 1947, is now director of the laboratory. Dr. Aborn's undergraduate education was in liberal arts, with graduate work in metallurgy leading to the Sc.D. degree from Massachusetts Institute of Technology in 1925. His career in the steel industry started in the blast furnace department of Bethlehem Steel Co. in 1920. As his interest turned to metallurgical research, he joined the staff at Watertown Arsenal, and later was associated with the research laboratory of applied chemistry at M.I.T. After two years in teaching and research at Harvard University, he joined the staff of the Fundamental Research Laboratory of U.S. Steel in 1930. During World War I he served in the Chemical Warfare Service, U.S. Army, and in World War II he was closely associated with special metallurgical research for the armed services under the direction of the Office of Scientific Research and Development. Among his special interests are stainless steels and welding, and in 1941 he was awarded the Lincoln Gold Medal of the American Welding Society. Dr. Aborn is a past chairman of the Publications Committee, and also served on the Educational Committee.

The 1954 Award for Scientific Achievement in the Engineering Sciences has been presented by the Washington Academy of Sciences to WILLIAM S. PELLINI for "notable contributions to metals processing and as a recognition for distinguished service to the casting and welding fields". Despite his specific welding and foundry interests (he was head of the welding research group and later of the combined welding and foundry group before being promoted to superintendent of the metallurgy division for the Naval Research Laboratory in 1954), Mr. Pellini does not consider himself a specialist in any one area of metallurgy; a diverse background in research preceded his association with the Laboratory staff in 1949. He attended Carnegie Institute of Technology on a scholarship, where "metallurgy entered his system irrevocably after a 5-min. interview with Dr. Mehl in his freshman year". He was graduated in 1940 with honors, stayed for two years at the Carnegie Tech Metals Research Laboratory, joined the Navy and was stationed at the Naval Proving Ground, emerging as a lieutenant colonel in 1946. In the next three years, before joining the Naval Research Laboratory, he was associated with American Brake Shoe Co. and the A.E.C. at Oak Ridge. Mr. Pellini has published approximately 80 papers (his thesis won the national prize in the A.I.M.E. student paper competition), and is a frequent speaker before chapters, American Foundrymen's Society and the American Welding Society. He also contributes generously to committee work for the Welding Research Council, A.F.S., other technical societies and the Government.

**Joseph I. Farmer**, formerly chief engineer of Ferro Powdered Metal Corp., is now manager of the powdered metal department of Ford Motor Co., Detroit.

**E. L. Bartholomew, Jr.** has been promoted from associate professor to full professor in charge of the physical metallurgy division of the department of mechanical engineering at the University of Connecticut. Dr. Bartholomew recently completed a two-year research project for U.S. Army Ordnance on grain growth and recrystallization in titanium and alloys.

**Leslie Clifton Whitney**, manager of development engineering, wire and cable division, of Copperweld Steel Co., Pittsburgh, has been elected president of the Wire Association. A past chairman of the Pittsburgh Chapter, Mr. Whitney has been associated with Copperweld Steel Co. since 1930. He is a graduate of Lehigh University, with a degree in metallurgical engineering.

**Anson B. Albree**, formerly with Rolled Alloys, Inc., Detroit, is sales manager for Aluminum Foils, Inc., Jackson, Tenn.

**R. L. Rickett**, formerly assistant supervisor on the Fundamental Research Laboratory Staff of United States Steel Corp., Kearny, N. J., is now an assistant director in physical metallurgy.

**George F. Comstock** has recently retired as assistant director of research, Titanium Alloy Mfg. Div. of the National Lead Co., Niagara Falls, N. Y. With over 40 years of experience in the field of titanium alloys, Mr. Comstock is the inventor of a number of basic alloys and is author of the recently published "Titanium in Iron and Steel". He now resides in Florida.

Complete valve with solenoid on top.

# REVERE

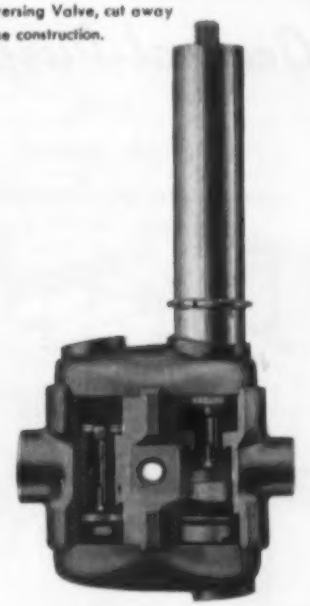
## collaboration helped make this reversing valve possible

The valve shown here is unique. It is made by Ranco, Incorporated, Columbus, Ohio, and is being supplied to manufacturers of air conditioners that either cool or heat, according to the temperature. When the thermostat calls for cooling, a solenoid moves the valve to the cool position; when heat is required, the operation is reversed, automatically.

Naturally, the development of this valve took a long time. For some five years the Revere Technical Advisory Service has been collaborating closely with Ranco engineers on design and materials for control valves of various types. When the new idea was under development, Revere was called in because non-magnetic brass and copper would be required for the body. Designs were mutually studied, and it was decided to make the main portion of the body from a brass forging, which would lessen machining and provide a dense, non-porous, non-leaking part. Many thousands of these reversing valves have been shipped to makers of ½, ¾ and 1-horsepower units, without a single forging rejection. One important feature of the forging is that it makes possible silver brazing the inlet and outlet tubes so quickly that no damage is done to the synthetic valve washers. Ranco feels that the valve has a tremendous future, offering as it does completely automatic selection of heating or cooling.

When you have a new project on your boards, involving aluminum, brass or copper, we suggest you get in touch with the Revere Technical Advisory Service. Its knowledge added to yours may make your products better. See the nearest Revere Sales Office.

Ranco Reversing Valve, cut away to show the construction.



Revere Brass Forging is supplied to Ranco already machined.

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## Personals . . .

**Donald E. Dorney**, formerly materials engineer in the technical section, polychemicals department, E. I. du Pont de Nemours & Co., Belle, W.Va., entered active duty in the U.S. Army as a second lieutenant, and is now stationed at Aberdeen Proving Grounds, Md.

**Arthur Herbener** has accepted a position as product engineer at the research center of Vanadium Corp. of America, Cambridge, Ohio.

**Philip B. Schneider** has been appointed sales representative for the state of New Jersey by the Stainless Sales Corp., New York, N. Y.

**Harold J. Holmes**, formerly chief engineer for Atlas Press Co., Kalamazoo, Mich., is now executive engineer and assistant to vice-president, engineering, at Heald Machine Co., Worcester, Mass.

**F. S. Wartman** has resigned as head, electrometallurgical branch, metallurgical division, Region III, U.S. Bureau of Mines, to accept a position on the technical staff of Cramet, Inc., Chattanooga, Tenn.

**Monroe J. Hordon** has accepted a position as research assistant in the department of metallurgy, Massachusetts Institute of Technology. Mr. Hordon graduated from Polytechnic Institute of Brooklyn in June 1954.

**William W. Austin**, formerly professor of metallurgy and administrative assistant in the department of mechanical engineering at North Carolina State College, will head the newly established department of mineral industries at that institution. The new department is the result of consolidation of previously existing curricula in ceramic and geological engineering and instructional work in metallurgy. Plans for the future call for the addition of a complete curriculum in metallurgical engineering, including both graduate and undergraduate programs, as well as research activities to be integrated with the nuclear research program presently under way in the college-owned nuclear reactor.

**W. E. Hoare**, who has held the post as head of tinplate section at the Tin Research Institute's headquarters in London, England, for the past six years, has been appointed an assistant director. Dr. Hoare is well known in tinplate circles in the U.S.A., where he is a frequent visitor.

**Donald G. Stallman**, who graduated from the University of Washington last December with a B.S. degree in metallurgical engineering, now holds a position as quality analyst in the nondestructive testing unit at Boeing Aircraft Co., Seattle, Wash.

**John L. Petz** is president of the recently organized Petz-Emery, Inc., in Pleasant Valley, N. Y., which will manufacture a newly developed line of dial indicators and other measuring instruments. Mr. Petz has over 45 years' experience in instrumentation, tool engineering and manufacturing. He was associated with Electromatic Typewriter, Inc., Rochester, N. Y., for 21 years, 12 of these as chief engineer. For the last seven years he has been a partner in the J. L. Petz Co., Poughkeepsie, N. Y.

**Joseph L. Petz**, who was elected secretary-treasurer of Petz-Emery, has been engaged in all phases of tool engineering and manufacturing for 40 years. He was associated with the International Business Machines Corp., Poughkeepsie, N. Y., for 13 years, and a partner in J. L. Petz Co. for the past five years.

## Personals . . .

**Vernon C. Robinson** ⊕ has joined the development and research division of the International Nickel Co., Inc., as a member of the Twin Cities technical field section at Minneapolis, Minn. A graduate in metallurgical engineering of the University of Minnesota, Mr. Robinson before his present appointment was associated with the Norma-Hoffman Bearing Corp., Stamford, Conn., as a field engineer.

**John D. Joyce** ⊕ was recently appointed industrial sales manager of the industrial division of Blue M Electric Co., Blue Island, Ill. Mr. Joyce, formerly associated with Claud S. Gordon Co., Chicago, was graduated from Purdue University.

**Uriah W. Davis** ⊕ has been appointed chief metallurgist for the Titusville, Pa., plant of Universal-Cyclops Steel Corp. Since 1948, Mr. Davis has been associated with the company's metallurgical staff at its Bridgeville, Pa., plant, and headed the process development group.



**Robert J. Stoup** ⊕, plant metallurgical engineer at the Ambridge, Pa., plant, Spang-Chalfant Div. of the National Supply Co., has been appointed assistant chief field engineer, with headquarters at Tulsa, Okla. Mr. Stoup, who graduated from the University of Pittsburgh in 1931, joined National Supply in 1936 as assistant metallurgist in the research department of the Ambridge plant. During World War II he was in charge of heat treating and production of gun tubes, and served as a member of the Industry Advisory Committee on Gun Forgings of the United States Ordnance Department. He was appointed plant metallurgical engineer in 1950.

**Howard N. Farmer, Jr.** ⊕ has joined the development and research division of the International Nickel Co., Inc., as a member of the West Coast technical field section at Los Angeles. A graduate of the California Institute of Technology, Mr. Farmer holds the degree of master of science in mechanical engineering. Before joining International Nickel, he was chief research engineer with the security engineering division of Dresser Operations, Inc., Whittier, Calif. Previously, he served as metallurgist with the Angelus Steel Treating Co., Vernon, Calif., teaching assistant at the California Institute of Technology, and assistant project engineer with the Aero Products Div., General Motors Corp., Dayton, Ohio.

**Norman N. Breyer** ⊕, formerly chief of the Armor Section, Detroit Arsenal, has joined Continental Foundry & Machine Co., East Chicago, Ind., as metallurgist for the armor division. Mr. Breyer is a graduate of the Michigan College of Mining and Technology, and received his master's degree from the University of Michigan.

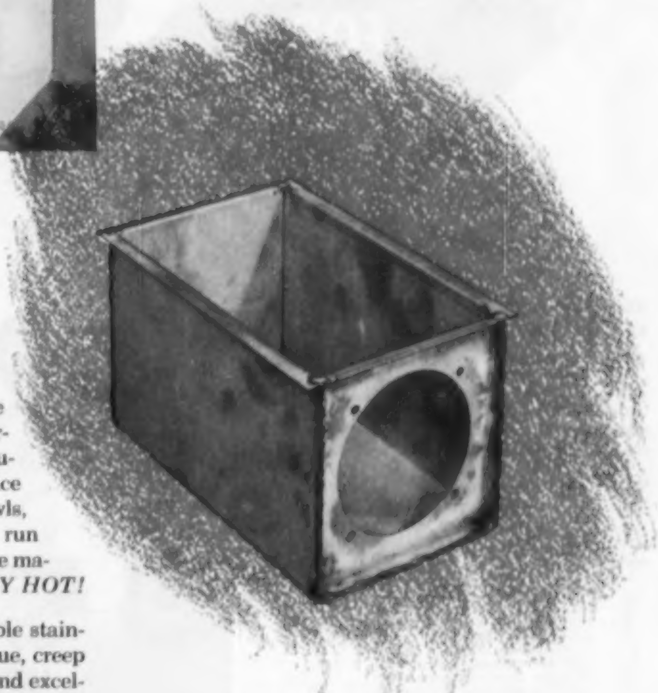
**Fred B. Riggan** ⊕, former vice-president in charge of research and development for the Key Co., East St. Louis, Ill., and consultant to the steel foundry industry, has joined Texas Steel Co., Fort Worth, Tex., as chief metallurgist. Mr. Riggan has also served as chemist for National Cast Iron Pipe Co., Tarrant, Ala., metallurgist for Stockham Valve & Fitting Co., Birmingham, Ala., and as an instructor at Howard University.

*If it's meant to get*

# HOT

*...use*

# CRUCIBLE STAINLESS



Crucible Type 430 firebox for the Perfection OC 90V Oil-Fired Furnace.

Say *"stainless steel,"* and most everyone thinks of bright appearance . . . corrosion resistance . . . strength without excess weight. But these properties are actually secondary in some applications.

As an example, take stainless steel's remarkable resistance to heat. That's the reason why The Perfection Stove Company uses types 309 and 430 Crucible stainless steels for its gas- and oil-fired furnace components — fireboxes, throat and burner bowls, combustion chambers, and baffles. In the long run stainless is the most dependable and least expensive material they can use for these parts that get *REALLY HOT!*

Of course, in addition to heat resistance, Crucible stainless steels offer corrosion resistance . . . high fatigue, creep and structural strength . . . resistance to wear . . . and excellent workability. And at Crucible, stainless steels are made by specialists who are concerned only with special purpose steels. They welcome the opportunity to help you select the best grade for the job. *Crucible Steel Company of America, Henry W. Oliver Building, Pittsburgh 30, Pa.*

**CRUCIBLE** first name in special purpose steels

**Crucible Steel Company of America**

## Personals . . .

**Thomas L. Chase** recently became a partner to **R. E. Christin** in the Electric Heat Treating Co., Columbus, Ohio. Mr. Chase has been with the Western Automatic Machine Screw Co., Elyria, Ohio, for the past five years as a metallurgist in their heat treating and foundry divisions. He graduated from Ohio State University in 1949 with a degree in metallurgical engineering.

**Edward E. Hall** has been appointed technical director of Universal-Cyclops Steel Corp., Bridgeville, Pa. Formerly chief metallurgist at the company's Titusville, Pa., plant, Mr. Hall will assume company-wide responsibility for the technical aspects of toolsteel production. He has been a member of the metallurgical staff of Universal-Cyclops since 1935, and is vice-chairman of the Northwestern Pennsylvania Chapter.



**A. D. Wagner**, formerly chief metallurgist of Hudson Motor Car Co., is now associated with Ira S. Latimer Co., Detroit. Mr. Wagner is secretary-treasurer of the Detroit Chapter.

**Edward B. Story** is retiring as chief metallurgist for the A. M. Byers Co., Pittsburgh, after 38 years of service. He is retained by the company in the capacity of consultant. Mr. Story is a graduate of the University of Cincinnati, and co-author of the textbook "Wrought Iron, Its Manufacture, Characteristics and Applications".

**Albert P. Gagnebin** has been appointed assistant manager of the nickel sales department of the International Nickel Co., Inc., New York. Co-inventor of the company's "ductile iron" and co-recipient in 1952 of the Peter L. Simpson Gold Medal Award of the American Foundrymen's Society for "outstanding work and development in the field of spheriodal cast iron", Mr. Gagnebin joined the company's research laboratory at Bayonne, N. J., in 1932 and has been a member of the development and research division in New York since 1949. He received his bachelor of science degree from Yale University in 1930 and his master of science in metallurgy in 1932.

**William H. Rice** is a recent addition to the technical staff of Electric Steel Foundry Co., Portland, Ore., and will work on cast weldment design and cast fabrications, as well as serve as a consultant on problems relating to the welding of high alloys. Dr. Rice served for 15 years as head of the welding department of Oklahoma Agricultural and Mechanical College. For the past two years he has been on leave of absence from Oklahoma A. & M. for the purpose of working for his doctorate at Oregon State College.

**Frank Romanoff** has been named technical director in charge of research and production processing operations at both the Chicago and Bethlehem plants of Apollo Metal Works.

**Louis W. Horvath** is now executive vice-president and sales manager of Jet Combustion, Inc., Chicago.


You can design light weight, longer life, and economy into your products by including N-A-X HIGH-TENSILE in your plans.

- It is 50% stronger than mild steel.
- It is considerably more resistant to corrosion.
- It has greater paint adhesion with less under-coat corrosion.
- It has high fatigue life with great toughness.
- It has greater resistance to abrasion or wear.
- It is readily and easily welded by any process.
- It polishes to a high lustre at minimum cost.

And with all these physical advantages over mild carbon steel—it can be cold formed as readily into the most difficult shaped stamping.

When you next start to redesign, get the facts on N-A-X HIGH-TENSILE. It's produced by Great Lakes Steel—long recognized specialists in flat-rolled steel products.

N-A-X Alloy Division

**GREAT LAKES STEEL CORPORATION**

Ecorse, Detroit 29, Mich. • A Unit of

NATIONAL STEEL CORPORATION

## Personals . . .

**Leonard C. Schmidt** has been appointed works manager in charge of tooling and production activities at Worcester Pressed Steel Co., Worcester, Mass. Mr. Schmidt was formerly manager of manufacturing methods at General Electric Co., Schenectady, N. Y. He received his bachelor of science degree in industrial engineering from the University of Pennsylvania in 1926.

**Charles W. Mote** has been appointed assistant plant manager of the Dodge Forge Plant of Chrysler Corp., Detroit. Mr. Mote has been associated with the Dodge Division since 1933, serving in various capacities, including foreman, general foreman and superintendent. In June 1954 he was made assistant general superintendent, and later in the year was assigned to special duties as staff assistant to the plant manager, a position he held until his newest appointment.

**Gilbert R. Jarman** has been appointed general sales manager of Marshall Steel Co., La Grange, Ill. For the past ten years, Mr. Jarman has been with the Columbia Tool Steel Co., Chicago Heights, Ill., and since 1949 has been the southwest district manager for that firm with offices in St. Louis, Mo.

**Ralph F. Jumet**, formerly quality control engineer, senior grade, Atomic Power Div., Westinghouse Electric Corp., Pittsburgh, has accepted a position as production metallurgist with the Norton Air Force Base in San Bernardino, Calif.

**Jerome B. Malerich** is presently working as a technical engineer in the materials and processes unit of the Small Aircraft Engine Laboratory of General Electric Co., Lynn, Mass.

**Raymond J. Thomas**, past chairman of the Lehigh Valley Chapter and formerly chief metallurgist of the Studebaker Corp.'s Aircraft Engine Div., New Brunswick, N. J., is now ordnance metallurgist at the Raritan Arsenal, Metuchen, N. J.

**Frederic L. Moffet** has been appointed chief metallurgist for Crucible Steel Co. of America, heading a department of 40 metallurgists, chemists, and technicians at the company's Park Works, Pittsburgh. A native of Pittsburgh, Mr. Moffet is a metallurgical engineering graduate from Carnegie Institute of Technology. Upon graduation in 1934, he joined Crucible as a metallurgist at the company's Crescent Laboratory in Pittsburgh. He was later assigned to the LaBelle Works, where he was made chief metallurgist in 1940. In 1945, when LaBelle operations were consolidated with other Crucible facilities, Mr. Moffet was transferred to the company's Park Works as a contact metallurgist, which position he held until his current promotion. He succeeds **William H. McCormick**, whose appointment as manager of sales for Crucible's Park Alloy and Carbon Division was announced recently.

**Herbert M. Meyer**, research metallurgist for Armour Research Foundation, Chicago, since 1951, has accepted a position with Watertown Arsenal Laboratory as chief of the metals research branch.

## Personals . . .

**Jerome Strauss**, vice-president of Vanadium Corp. of America and a graduate of Stevens Institute of Technology, class of 1913, recently received the Stevens Honor Award. Mr. Strauss is an authority in metallurgy, particularly in ferro-alloys, and holds ten major patents covering inventions in those fields.

**Robert S. Neilson** has been appointed engineering specialist in metal forming and drawing by Baldwin-Lima-Hamilton Corp., Philadelphia, serving as consultant for the company's field sales personnel and metalworking customers on problems involving capacity and tool selection as required in hydraulic press application. Prior to joining Baldwin, Mr. Neilson was chief tool engineer for the Scaife Co., Pittsburgh, for 15 years.

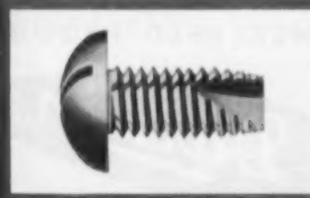
**John C. Neemes, Jr.**, of the International Nickel Co., Inc., has been elected chairman of the Mining and Metallurgy Committee of the Alumni Association of the Institute of Technology, University of Minnesota. A metallurgical engineer, Mr. Neemes has been in charge of the Inco development and research division's Twin Cities technical field section at Minneapolis, Minn., since it was opened in January 1946.

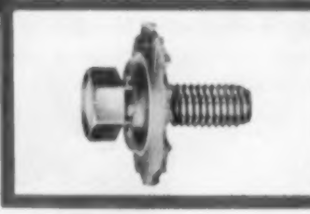
**George E. Schultz** has been named general foreman, pattern shop and brass foundry, at the Norwood Works of Allis-Chalmers Mfg. Co. Mr. Schultz is a mechanical engineering graduate of Massachusetts Institute of Technology, and since 1952 has been a metallurgist in the Allis-Chalmers development laboratory.

**Robert J. Knox** formerly staff metallurgist for the Aluminum Co. of America, Davenport, Iowa, works, has been transferred to the central metallurgical division at the company headquarters in Pittsburgh.

**Howard L. Sittler** is now associated with the Air Reduction Sales Co., Chicago, as welding engineer specializing in metal-arc welding electrodes. Mr. Sittler was formerly head of the welding engineering section of the research and development department of Arcrods Corp., Sparrows Point, Md.

# Beat THIS for Low Heat-Hour Cost!





*Heat-treating department at the Shakeproof Division of Illinois Tool Works, Elgin, Ill. A Nichrome muffle in one of these gas furnaces, operating at temperatures between 1500°F. and 1600°F., gave 36,732 hours of almost uninterrupted service between Sept., 1948 and April, 1954. Atmosphere consisted of ammonia and city gas.*

*In a rotary-type furnace in the same plant, a Nichrome retort operating at temperatures from 1600°F. to 1825°F., using ammonia and city gas, gave 17,248 hours of service.*

# 36,732 Hours of Service From a NICHROME* Muffle

That's the performance story from Shakeproof Division, Illinois Tool Works, Elgin, Ill., world-famous makers of Shakeproof® lock washers, thread cutting screws, terminals, and special fastenings. They produce fasteners of high quality, and they find it pays to use high quality equipment in their production. Especially when in the long run such equipment actually costs *less*.

For instance, they might easily have found a muffle with a lower initial cost than the Nichrome muffle they use in heat-treating their fastenings. But when you find that this muffle gave 36,732 hours of service over a period of 5½ years—the actual cost reveals Shakeproof as an intelligent buyer indeed.

Particularly so since a Nichrome retort in another of their gas furnaces, operating under somewhat higher temperatures and greater stresses, gave the same plant a total of 17,248 hours of service.

Whatever your heat-treating requirements, consult with us. Our business is keeping your *heat-hour costs* down to the absolute minimum—and we've had over 30 years of successful experience at doing just that. Our engineers will gladly make recommendations for your specific needs.

All furnace equipment by American Gas Furnace Co., Elizabeth, N.J.

*Nichrome is manufactured only by*

**Driver-Harris Company**

**HARRISON, NEW JERSEY**

**BRANCHES: Chicago, Detroit, Cleveland, Louisville, Los Angeles, San Francisco**

*T. M. Reg. U. S. Pat. Off.

**MAKERS OF WORLD-FAMOUS NICHROME AND OVER 80 ALLOYS FOR THE ELECTRICAL, ELECTRONIC, AND HEAT-TREATING FIELDS**

## Steel for Cannon—Sources of Information

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*(Continued on p. 136)*

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*(Continued on p. 138)*

## Steel for Cannon . . .

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## Cermets . . .

*(Continued from p. 82)*

Due to the fact that very little was known about metal-boron systems at the outset of boride research, basic work on phase diagrams delayed the making of bodies and shapes for testing. However, it appears that the "Borolites"* are catching up with the carbides and will soon be commercially available in parts for service in temperature ranges in which carbides will prove to be useless.

Finally, the nickel aluminides have come very much into the foreground because of their relatively good impact. However, it cannot be expected that news about the serviceability of nickel aluminide parts will appear before the end of 1955.

The three materials, nickel aluminide, titanium-carbide-base cermets and the borides have a promising future in the temperature scale above that point where superalloys fail. First, nickel aluminides at 1600, titanium-carbide-base cermets at 1800, and borides up to 2100° F.

Close cooperation of engine designers with private research and development groups is much to be desired. There can be no doubt that joint efforts will provide industry very soon with new materials for these extremely high operating temperatures.

*"Borolite" is the trade name applied to metal boride products as marketed by Borolite Corp. of Niagara Falls, N.Y.

# Symposium on Stress-Corrosion

*By W. D. Robertson**

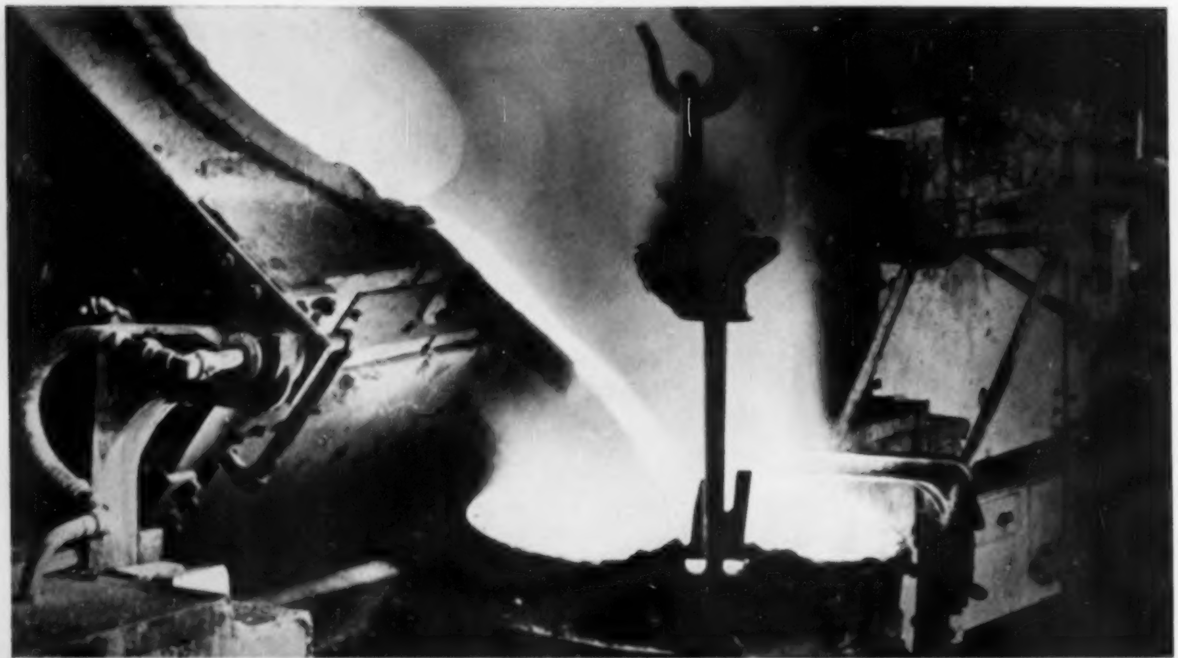
Ten years ago a symposium on stress-corrosion cracking was held in Philadelphia under the joint auspices of the A.S.T.M. and the A.I.M.E. At that time the problem was recognized as serious and likely to become more so. This prediction has come true. Stress cracking has become a major problem as a result of the increasing loads and severity of environment under which components now operate. Owing to a limited knowledge of the corrosion mechanism, except in a few cases of which age hardening aluminum alloys are one of the best examples, the appearance of stress cracking in new alloys or unfamiliar environments is essentially unpredictable and often catastrophic in consequence. Still, our understanding of metallic structure has advanced very considerably during the past decade – especially with respect to the significance of imperfections of various types and their relation to different structure-sensitive properties.

This symposium was organized by the Corrosion Div. of the Electrochemical Society to reveal new, critical experiments relating to the mechanism of stress cracking and embrittlement and to determine whether, under the stimulus of recent metallurgical developments, a better understanding of this phenomenon was emerging from the mass of empirical data and speculation already available.

The first of 12 papers was presented by Julius J. Harwood, head of the metallurgy branch of the Office of Naval Research. Mr. Harwood's contribution, "Introductory Review of the Problem", was a general survey of current understanding of the mechanism of corrosion. It was observed that we are dealing with brittle failure in normally ductile materials and that the problem may be considered, in fact must be considered, as a brittle fracture process.

*(Continued on p. 142)*

*A report of "Symposium on Stress-Corrosion Phenomena" held during the 106th Meeting of the Electrochemical Society, Oct. 3-7, 1954 at Boston, Mass. Professor Robertson is in the department of metallurgy at Yale University, New Haven, Conn.



# *6 tons of steel melted and poured every 2½ hours*

SPEED . . . CONTROLLED QUALITY . . . ECONOMY —these advantages are enjoyed on every melt, ferrous or non-ferrous, in Ajax-Northrup induction furnaces. This furnace for example, turns out a six-ton charge of nickel alloy—precisely alloyed and virtually free of impurities—every 2½ hours.

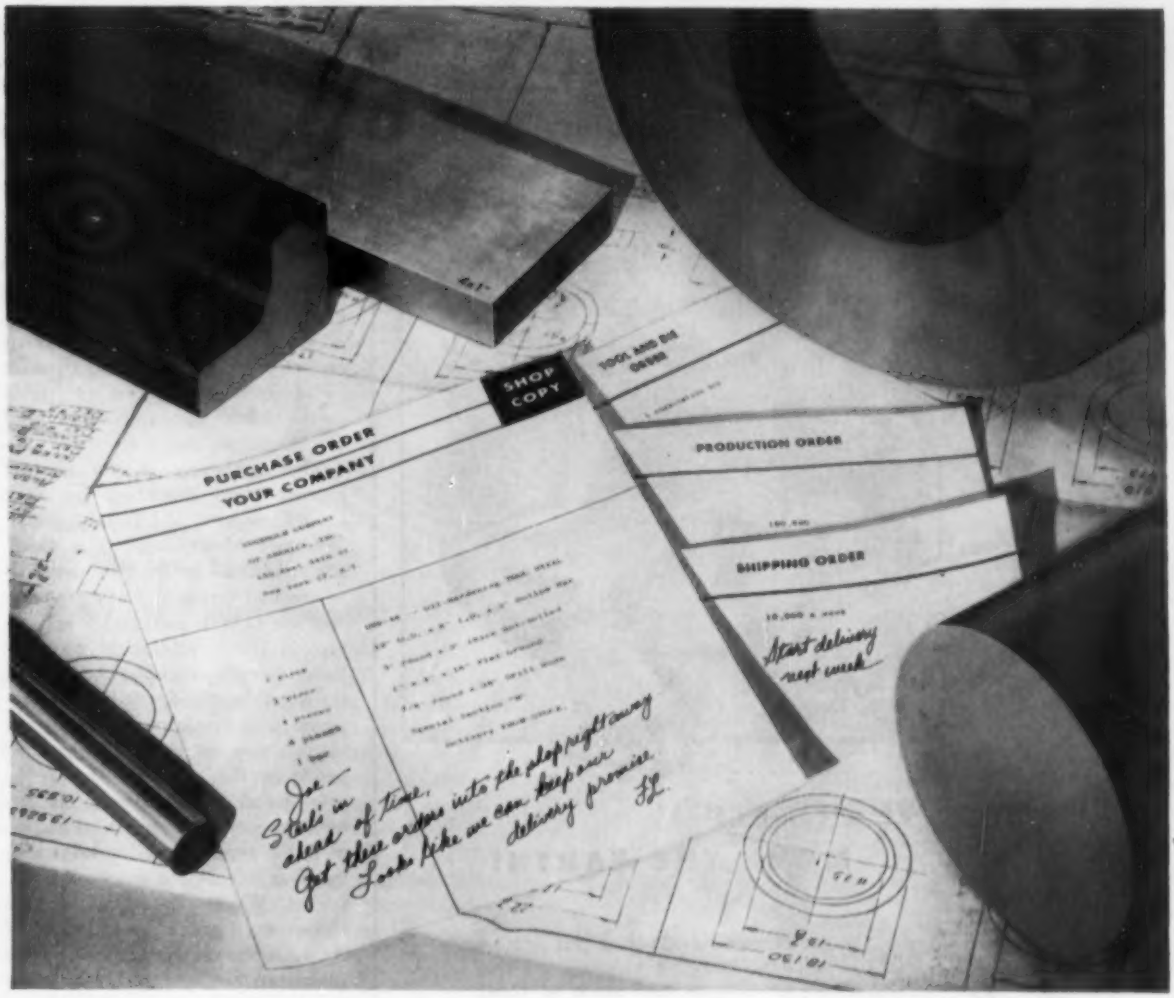
Ajax induction melting puts substantially all the heat in the charge proper. No power is wasted in superheating crucible or refractory, and little heat escapes into the room. Speed of melting and electromagnetic stirring insure perfect alloys every time.

Ajax has been building induction furnaces for all metals since 1916. Installations capable of producing up to 20,000 pounds of metal per hour are in operation, and more and more foundries are switching to Ajax-Northrup melting as they discover its economy and advantages. Learn why in Bulletin 27-B, available upon request to Ajax Electrothermic Corporation, Trenton 5, New Jersey.

*Associated Companies: Ajax Electric Company—Ajax Electric Furnace Co.—Ajax Engineering Corp.*

**AJAX NORTHRUP** *SINCE 1916*

**INDUCTION HEATING-MELTING**

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Furthermore, the need for tool steel is usually urgent—sometimes you need it "yesterday". Therefore, place your order with a source that has an extremely wide variety of grades, shapes, sizes, and finishes in stock—Uddeholm.

For instance, UHB-46 oil-hardening tool steel is stocked in all these forms: drill rods, flat ground stock, hot-rolled bars, special sections, and hollow bars.

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## Stress-Corrosion . . .

The mechanism was discussed in terms of the production of susceptible paths by chemical action and the mechanical propagation of cracks by applied stress. It was emphasized that a threshold stress is frequently observed, analogous to the static fatigue of glass and to the delayed fracture of ferrous metals in hydrogen. Since the actual failure is apparently mechanical, the problem is one of determining the mechanism of chemical production of stable cracks that act as stress-raisers and can propagate under stress.

The mechanics of the fracture process were described by Prof. Egon Orowan of M.I.T. in his paper, "Fracture Mechanism". The requisite conditions for fracture were developed in terms of surface energy and the Griffith mechanism of fracture in brittle substances was outlined. Energy conditions at a crack tip were described, and it was proposed that crack propagation may involve the severing of cohesional bonds at the leading edge of the crack by chemical reaction. The latter concept was introduced to explain the pronounced dependence of cracking on environment.

Prof. W. D. Robertson of Yale University, general chairman of the symposium, presented results ("Crystallography and Corrosion Cracking") of a current study of homogeneous copper-gold alloys in which pronounced structure-dependent corrosion is observed. It was shown that copper is preferentially removed in ferric chloride from any structural discontinuity and, in particular, from grain boundaries, incoherent twin boundaries and subgrain boundaries in single crystals that have been grown from the liquid. It was also demonstrated that slip clusters in single crystals are preferentially attacked and that cracks are triggered at microscopic sites of attack in the slip cluster; the resulting cracks are not propagated in the plane of the slip band, but spread transversely to the stress axis. The type of crystallographic plane exposed is a factor in determining the chemical attack and, consequently, the subsequent crack. Corrosion at microscopic sites is a prerequisite to cracking, which varies with the

*(Continued on p. 144)*

# TEST THESE Corrosion-Resistant Alloys

These standard spool-type test specimens of HASTELLOY alloys are available on request.

## ... and see for yourself how economical they are

The only way you can be sure that a corrosion-resistant material will work in your plant is to test it under actual operating conditions. Laboratory tests will give you some idea of what to expect, but they don't show the effects of the variables involved in production operations. That is why we have prepared standard test specimens of HASTELLOY nickel-base alloys . . . and they are available to you without cost.

Test these alloys yourself against the materials you are now using, or against others that you are considering using. Prove to yourself that they have exceptional corrosion resistance . . . high mechanical strength, even at elevated temperatures . . . and that they are economical to use. We can support these claims with records of laboratory tests and with case histories of actual installations in chemical, petroleum, textile, and metalworking plants over the past 20 years. But don't take our word for it—see for yourself.

Use the handy coupon below to order your samples of HASTELLOY alloys. Alloys B, C, and F are available in either cast or wrought forms, while alloy D is supplied as castings only. If the equipment you have in mind is to contain welded joints, be sure to advise us, so that we may furnish you with welded samples.



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## Stress-Corrosion . . .

alloy system and the environment. The site at which a crack is triggered in a homogeneous alloy is apparently directly dependant on the inherent structure of the solid solution, or the structural characteristics produced by plastic deformation.

Prof. Ludwig Graf of the Max-Planck Institute at Stuttgart, Germany, who could not be present in person, submitted the paper "Stress Corrosion of Homogeneous Alloys", a comprehensive summary of his work on this subject. An extensive study of silver-gold and copper-gold alloys in a variety of media indicates that the observed cracking in these systems is a property of the solid solution and is not associated with precipitates or impurities. Susceptibility is determined by the alloy composition, relative to the environment. In gold alloys the phenomenon of a "parting limit" is observed at about 40 at. % gold and is applicable to cracking as well as solution of copper or silver. Homogeneous alloys are susceptible when the base metal is chemically less noble than the alloying components; alpha brass is included in this rule because, relative to ammonia, copper is the active component owing to the formation of the copper-ammonia complex. On the other hand, homogeneous alloys whose base metal is more noble than the alloying component are not susceptible – for example, the alloys high in gold.

The second session began with "Grain-Boundary Structure", by Bruce Chalmers of Harvard University. Because many of the cracking phenomena are associated with boundaries, it is obviously necessary to consider the atomistic picture of boundary structure. Professor Chalmers reviewed experiments on boundary properties, emphasizing those which evaluate intrinsic properties of the boundary and which, accordingly, are orientation-dependent. It appears that extensive developments in this field have not been sufficiently studied in connection with the problem of stress cracking – the reason, of course, being the difficulty of isolating the boundary for the purpose of chemical experiments.

The preceding papers were primarily concerned with homogeneous

*(Continued on p. 146)*

## Stress-Corrosion . . .

alloys. Heterogeneous alloys were considered by E. C. W. Perryman of Aluminium Laboratories Ltd., Canada. His paper, "Metallurgical Aspects of Stress-Corrosion in Aluminum Alloys", was a report on the effect of precipitation and cold work on the stress-corrosion properties of aluminum-magnesium alloys. In particular, Dr. Perryman considered the reasons why stress-corrosion cracking occurs when discrete, separated precipitate particles are present at the grain boundaries. The effect of small amounts of cold work in increasing the rate of precipitation at grain boundaries was explained and also the reasons why large amounts of cold work lead to layer corrosion.

The inherently brittle properties of Al-Cu, Al-Zn and Al-Zn-Mg alloys were described and a hypothesis based on Gayler's "light phenomenon" was advanced to explain delayed intercrystalline failure that occurs in these alloys when stressed in a noncorroding environment.

Returning again to homogeneous alloys, Rudolph Speiser and J. W. Spretnak of Ohio State University dealt with the problem of grain-boundary composition in terms of Gibb's adsorption equation in their report, "Role of Surface Adsorption of Solute Atoms in Stress-Corrosion of Alloys". It was shown that, in binary alloys, the component having the lower surface tension is positively adsorbed at the boundaries. If the adsorbed component is electrochemically more active in the corrosive medium, then the boundary reacts at a faster rate than the adjacent grains and a crevice is formed. The effective width of the boundary region, different in composition than the average composition, was estimated as 20 to 50 angstroms. Accordingly, very weak corrosive media can produce a crevice of sufficient sharpness to initiate failure by cracking under the action of stress. Adsorption is significantly influenced by grain-boundary curvature which may explain, in part, the observed preferential attack at some of the grain boundaries.

At one time it was thought that stress cracking of stainless steel was quite well understood but recent work indicates that this is far from

*(Continued on p. 148)*

NO. 30 OF A SERIES

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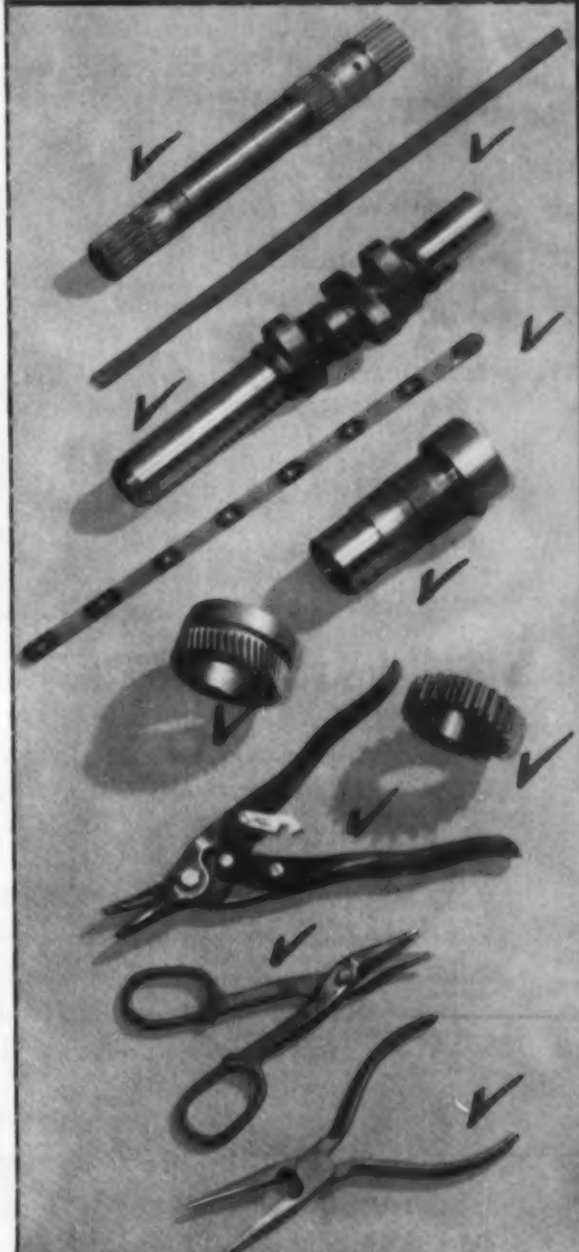

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## Stress-Corrosion . . .

the truth. The paper "Stress-Corrosion of Austenitic Stainless Steels", by C. Edeleanu of the Brown-Firth Research Laboratories in Sheffield, England, gave results of current experiments on this subject. These show that his previous work on the preferential corrosion and cracking of stress-induced martensite provides only a partial explanation for transgranular cracking in austenitic stainless steel. The mechanism of electrochemical reactions in chloride solutions was explained and it was concluded that the function of corrosion is to trigger the mechanical action that is primarily responsible for failure.

*(Additional papers in the symposium will be reviewed in a subsequent issue.)*

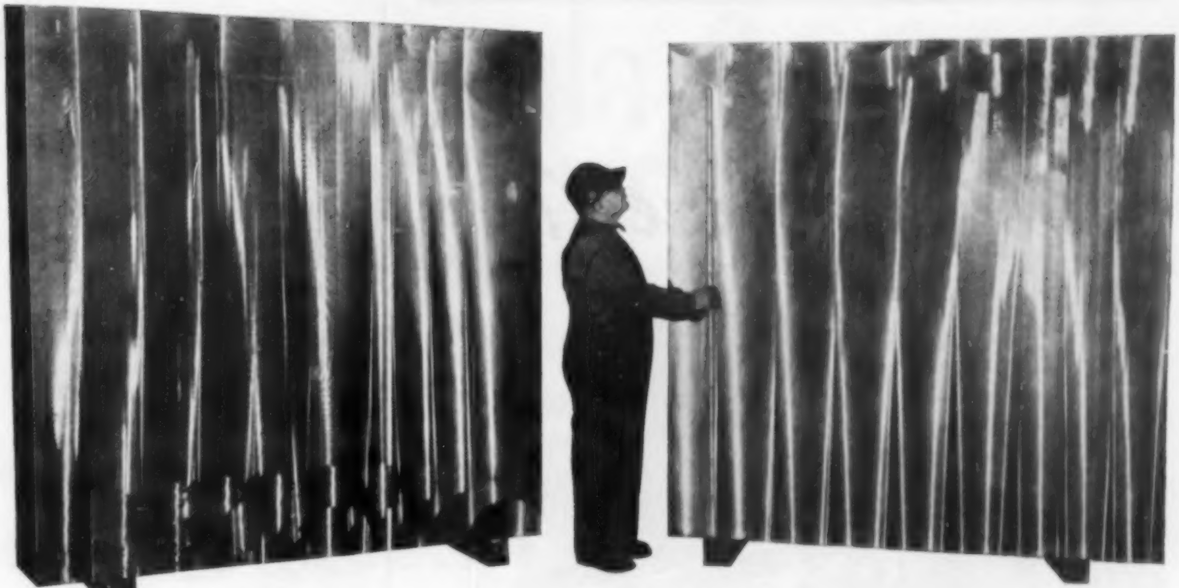
## High-Purity Nickel Powder*

After five years of pilot-plant operations and a cost of two and a half million dollars, the Sherritt Gordon Metallurgical Research Div., Ottawa, Canada, will start the commercial application of its new process for making high-purity nickel powder at Fort Saskatchewan, Alberta. The regular run of nickel has a purity of 99.87% nickel, 0.1% cobalt, but specially high quality can be supplied to a purity of 99.97% nickel, 0.01% cobalt, and iron, sulphur, copper and lead all in the third decimal place. Electrolytic nickel as now commonly supplied contains from 0.1 to 0.8% cobalt and 0.02% each of iron and copper. Nickel shot made by the Mond process is free from cobalt, copper and sulphur, but may contain 0.1% carbon.

The Sherritt Gordon mine at Lynn Lake, Manitoba, has a reserve of 14 million tons of nickel ore containing about 1.25% nickel, and 0.6% copper, with some cobalt. Some 2000 tons of ore is treated daily, and nickel concentrate is produced to the extent of 235 tons of nickel-copper-

*(Continued on p. 150)*

*Digest of "Production and Properties of High-Purity Nickel Powder", by F. A. Forward, *Journal of the Institute of Metals*, Vol. 82, May 1954, p. 113-116.



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From steel making, where quality of material begins, through forging, heat treating, rough and finished machining, and metallurgical testing where quality of workmanship counts, Finkl standards are the highest. For 76 years we have proved that the best is the least costly in the long run. Next time you are considering die blocks or forgings choose Finkl and you will choose the finest.

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## Nickel Powder . . .

cobalt sulphide concentrate, which contains 10 to 16% nickel, 1 to 2% copper, 0.2 to 0.4% cobalt, 30 to 40% iron, 28 to 34% sulphur, 8 to 14% silica, and precious metals averaging 0.02 oz. per ton.

This nickel concentrate will be treated by an ammonia leaching process at the Fort Saskatchewan refinery. The process consists in mixing the concentrate with ammonia, air and water in mechanically agitated horizontal autoclaves at a pressure of 100 psi. The nickel, copper and cobalt are dissolved and recovered as amines. Most of the sulphur is oxidized to sulphate, thiosulphate, thionate and sulphamate ions. The iron, after being converted into hydrated ferric oxide, is filtered out and discarded, together with silicates and other insoluble matter. The solution containing the nickel, copper and cobalt is distilled to remove and recover ammonia; the thionates are decomposed. This provides sulphide ions that precipitate the copper as sulphide, which is filtered off. The nickel and cobalt amines, with some free ammonia, ammonium sulphate, thiosulphate, thionate and sulphamate are now in a copper-free solution. The completeness of the copper separation is indicated by the reduction of copper content from 8 g. per l. in the original solution to only 0.001 g. per l. after treatment. The nickel content is 45 g. per l. and the cobalt 0.7 g. per l. The copper-free solution is oxidized by heating in a mechanically stirred autoclave at about 350° F. with compressed air at 200 psi. The oxidized solution, still under pressure, is passed to a second autoclave at 450° F. The ammonium sulphamate hydrolyzes to ammonium sulphate. At this stage solid impurities are filtered off and the solution goes to a high-pressure holding tank. From the holding tank the solution is transferred to another horizontal autoclave where it is stirred while being treated with hydrogen under pressure. Under these conditions the nickel precipitates as uniformly fine particles of metal. The nickel can be precipitated preferentially in regard to the cobalt present. The hydrogen treat-

*(Continued on p. 152)*

# "Our Formula for Successful Quenching"

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Ragan Textile Rings must be uniformly hard, completely free of flaws and must have the smoothest finish obtainable.

To get these results from cold drawn seamless tubing, Ragan Ring Co. uses Sinclair QUENCHOL 521.

Ragan Ring says, "When, for economical reasons, we installed our own heat treating furnaces and were looking for one of the best quenching oils on the market to heat treat our top quality rings, we naturally looked to the man in whom we had absolute confidence – our Sinclair Engineer. He recommended QUENCHOL 521 and gave us a demonstration of what it would do. We put our new system into operation with QUENCHOL 521 in the tank.

"We are getting even better results than before – more uniform hardness, and no signs of flaws."

For a demonstration of this revolutionary new quenching oil, call your local Sinclair Representative, or write for a new booklet about QUENCHOL 521 to the Sinclair Refining Company, Technical Service Division, 600 Fifth Avenue, New York 20, N. Y.

**SINCLAIR CUTTING OILS and COOLANTS**

## Nickel Powder . . .

ment is repeated in cycles in a semicontinuous process. The size of the nickel particles that come down first is about 1µ in diameter; as the treatments are continued the particles grow until a size of about 50µ is reached. The nickel powder is washed with water to remove ammonia salts, steam dried, and packed in containers. The 50µ powder can be readily melted in induction furnaces, but a heel of molten metal is needed to start the melting.

Some uses indicated for this high-purity nickel are porous sintered compacts for battery plates, as a method for rapidly introducing nickel into cast iron, and the rolling of nickel sheets. The process is said to be rapid and comparatively inexpensive. HAROLD J. ROAST

## A New Toolsteel of High Cutting Capacity*

THE WARTIME shortage of tungsten and its resulting hardships on the Swiss Industry caused researchers at the Ludwig von Roll 'schen Steel Works Co. to reappraise the possibilities of substituting high-chromium alloys for tungsten high speed steels. This was an old idea, tried and abandoned after several unsuccessful experiments in various countries. The successful solution of this difficult, if not hopeless, problem would bring the additional advantage that complicated tools, like milling cutters, could be cast to shape.

In Mr. Collaud's own words, the problem now has been victoriously solved, as is attested by the availability of an entirely new kind of toolsteel sold under the trade name "Rollodur". Its cutting capacity is said to be fully equal to that of the best tungsten high speed steels, and even the "cast-to-shape" tools made of Rollodur can be made to have superior toughness through the proper heat treatment.

Previous attempts to develop high-chromium steels for cutting

*(Continued on p. 154)*

*Digest of "Contribution to the Study of 'Rollodur', A Steel of High Cutting Capacity", by Albert Collaud, *Von Roll Mitteilungen*, Vol. 11, July-December 1952, p. 73-91.

## New Toolsteel . . .

tools failed because of the extreme stability of the austenite that resulted from heating at high temperature. With the excessively high annealing temperatures generally used, this austenite did not transform to the structures having good machinability. Annealing above 1560° F. results in a mixture of the extremely hard to machine martensite and troostite, but annealing between 1290° F. and 1470° F. results in the formation of a sorbitic pearlite which machines with comparative ease. Annealing at 1370° F. results in hardness less than 300 Brinell.

The principal fault of high-chromium steels without tungsten is their insufficient high-temperature hardness. This deficiency leads to rapid wear as soon as one tries to exceed a certain production rate. Numerous attempts have been made to remedy this lack by adding other alloying elements to augment the high-temperature hardness. It has been demonstrated practically that the problem is far from insoluble; steels with over 8% chromium fortified with relatively minor additions of tungsten, molybdenum, titanium and cobalt can make excellent cutting tools, provided certain rules are observed. The original Rollodur patent recommended the addition of over 4% W and that the sum of tungsten, molybdenum, cobalt and vanadium should lie between 60 and 100% of the chromium content. Later patents recommended that alloys other than chromium (tungsten, molybdenum, vanadium) should exceed the chromium content and that the carbon should equal one-tenth the chromium plus two-tenths the vanadium contents. Only chromium and vanadium need be considered in determining the carbon content. For example, Rollodur 44-22 with 4% W contains 1.4% C, and Rollodur 108-32 has 10% W and 1.8% C.

Contrary to the prevailing opinion that retained austenite is detrimental to cutting tools, the author states that a certain amount of retained austenite increases production between grinds and is essential to a long service life. A tool with completely martensitic structure and maximum hardness is extremely brittle, and if it doesn't break in

service, its cutting edge will most surely crumble very fast. Toughness is necessary, especially in tools subjected to intermittent heavy loads, such as milling cutters. With Rollodur, high cutting efficiency is obtained through great depths of cut and heavy feeds rather than high cutting speeds.

The key to success is to control the amount of retained austenite. By doing that, Rollodur milling cutters have been made that, working under extremely heavy feeds and depths of cut, survived the destruction of the machine used in the experiment.

The amount of austenite retained can be controlled only through the interrupted quenching of the tools in a salt bath, but the author has failed to reveal a single detail concerning the interrupted quench (an exasperating omission to a reader whose interest has been aroused). However, he shows by hardness and dilatometric curves how the austenite content can be controlled within limits through repeated tempering at the recommended temperature of 1005° F. Three successive treatments at this temperature will transform the properly hardened steel to 100% martensite, transformation occurring during the cooling cycle following each tempering treatment. The third tempering, says the author (contradicting his statement that some retained austenite is required for maximum cutting capacity) is indispensable to improve the toughness of the tools by eliminating macrostress while not affecting microstress. He states that the latter is the source of the hardness.

The effect of variations in hardening temperature upon the retention of austenite is demonstrated with the aid of dilatometer curves taken during heating to the annealing temperature, 1470° F., and subsequent cooling of specimens, previously hardened at different temperatures. The austenite in the quenched steel reveals its presence by affecting the shape of the heating curve.

Variations in tungsten content have no effect on the hardening temperature. Austenite is not retained at temperatures to 2050° F., but at 2120° F. the effect is considerable and at 2190° F. 80 to 100% austenite is retained. When 5% cobalt is added, the steel will become completely austenitic upon quenching at 2120° F., and with

## New Toolsteel . . .

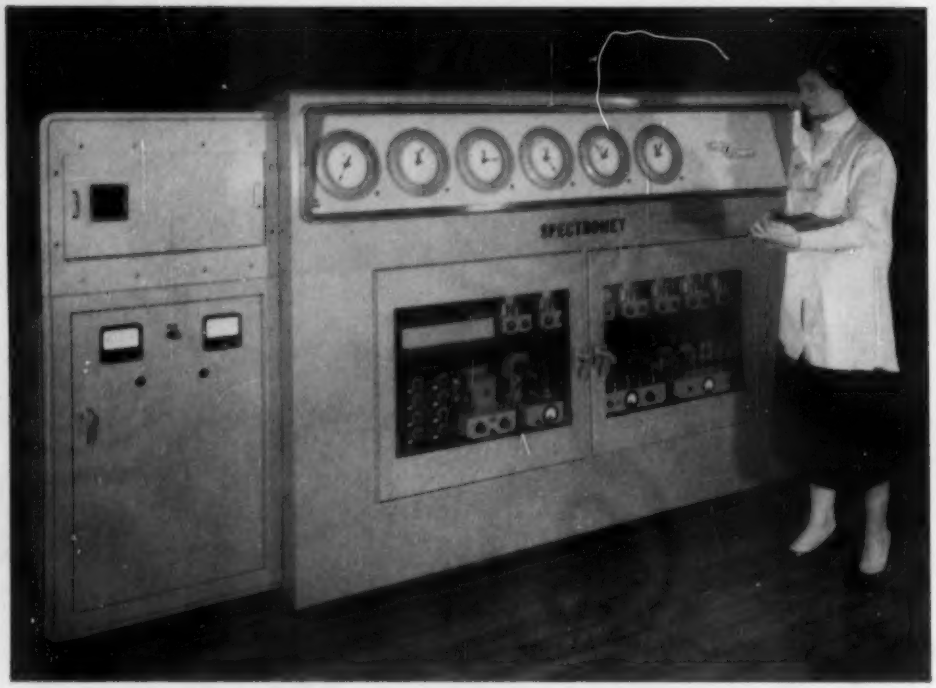
10% cobalt quenching at 2050° F. will produce the same result. The austenite alloyed with cobalt will transform on cooling from the annealing temperature while austenite free from cobalt will decompose at the annealing temperature, 1470° F. The retention of much austenite upon quenching, besides other advantages mentioned, makes warpage practically unknown. The high carbon of the Rollodur steels prevents grain growth through the interference of carbides, eliminating the need to control the time at the hardening temperature.

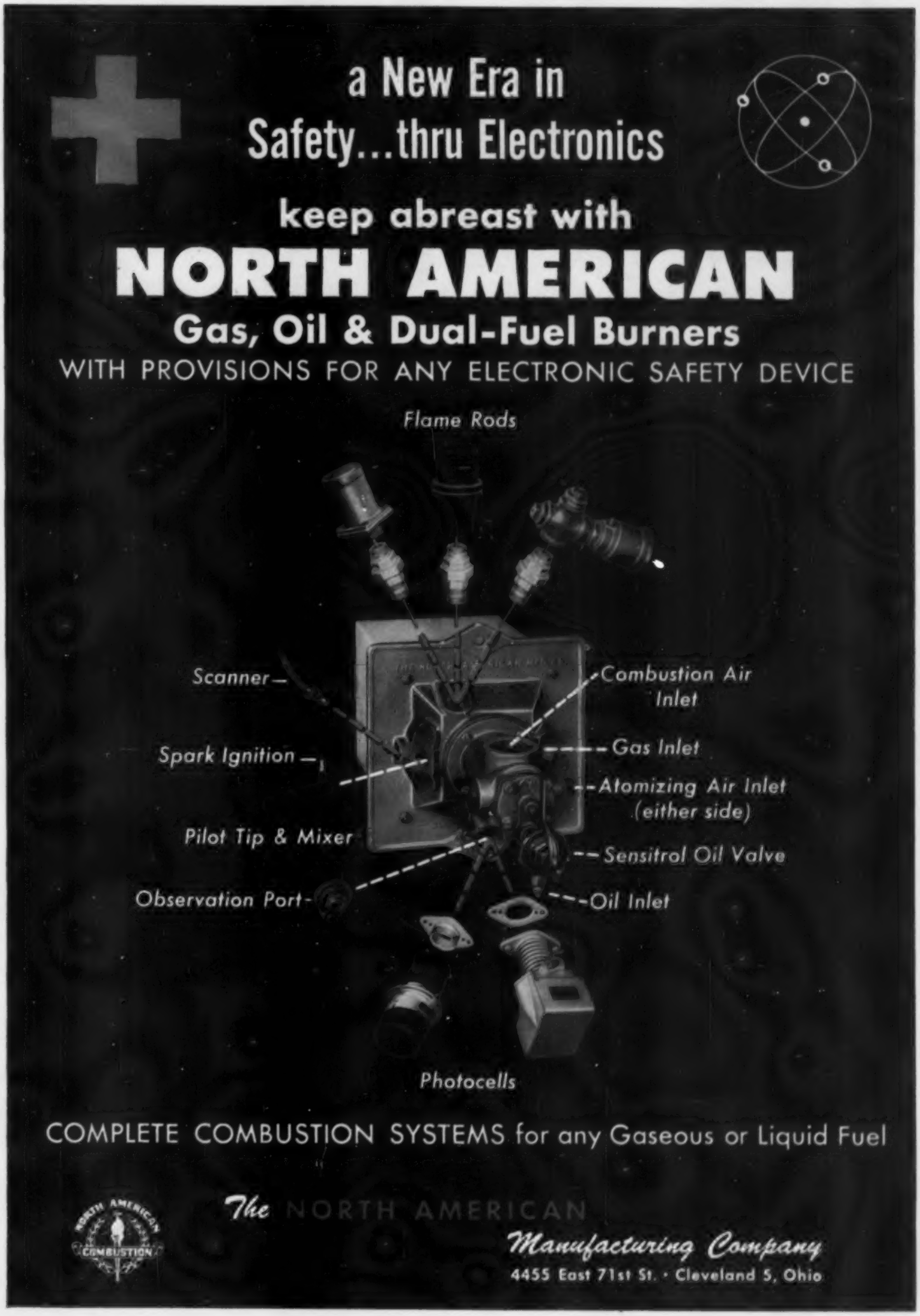
Rollodur is cast in sand that is subject to exceptional grading control and is much finer than the usual foundry sand. Since cast surfaces are completely smooth and free from defects, cast tools need very little machining.

The Gerlafingen laboratory has also perfected a Rollodur steel that can be hot worked with ease and fabricated by forging or rolling. Annealing is an important operation for this steel. Even the austenite resulting from heating at 2190° F., and which contains a large amount of dissolved carbides, can be transformed by first heating for an adequate period at 1650 to 1830° F. to produce a fine precipitation of carbides. A structure that is completely free of austenite will result after a sufficiently long hold at 1470 to 1290° F.—the critical interval. These statements are supported by dilatometric curves.

Aside from the fact that the discussion of the very heart of the development — the method of controlling the amount of austenite to be retained for maximum cutting efficiency — suffers from glaring inconsistencies and plain contradictions, the article is an extremely interesting one. Perhaps the author himself is not at fault. Possibly company censorship has deleted essential explanations to guard important trade secrets. Such censorship is not at all uncommon in our own country, but my impression is that the Europeans are considerably more jealous of trade secrets than the Americans. It calls to my mind the Editor's statement about fencing out more than is fenced in.

CARL A. LIEDHOLM

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# Oxidation Method for Measuring True Austenitic Grain Size*

THE LIMITATIONS of the A.S.T.M. test for austenitic grain size (McQuaid-Ehn test) have led to the examination of possible alternatives, one at least of which had been proposed before the McQuaid-Ehn procedure was accepted as standard. The chief drawbacks of the A.S.T.M. test are the lengthy austenitizing period and the introduction of additional carbon for the purpose of carburizing the grain boundaries. Both of these factors are known to affect the grain size that is to be measured, and the technique is, therefore, suspect. It is also known that with certain alloy steels no intergranular carbide network can be obtained.

The potentialities of a somewhat analagous method but using oxygen instead of carbon to attack the austenite grain boundaries were known at least as early as 1936. Thereafter various workers extended the technique and it became the subject of a French specification. All these techniques depended on extensive oxidation, either concurrent with or subsequent to austenitizing. This long period of oxidation caused penetration along grain boundaries, decarburization and the formation of a network of massive oxide globules. However, the time of treatment was significantly shorter than for the A.S.T.M. test and the likelihood of grain growth was correspondingly diminished. Check tests revealed that the oxidation technique gave a smaller grain size than the extended carburizing test. Reproducible results were difficult to obtain with the original oxidation techniques, mainly because the oxidation was allowed to go too far and the resulting massive oxides were difficult to prepare and examine microscopically.

The new procedure that has been evolved depends on the use of suitable etchants to reveal oxygen concentrations appreciably smaller than those needed to form iron oxide. It

*(Continued on p. 160)*

*Digest of "Perfecting the Oxidation Method to Permit Showing the True Austenitic Grain of Steels", by A. Kohn, *Revue de Metallurgie*, Vol. 57, February 1954, p. 129-137.

## Grain Size . . .

has been demonstrated that a very restricted oxidation treatment can reveal austenite grain boundaries; also, the technique developed for the method is said to reveal the true austenite grain boundaries with a much smaller risk of changing the grain size during the test.

Austenitizing is carried out in argon or nitrogen, which has been freed as much as possible from water vapor and oxygen by passing it over phosphorus pentoxide and a heated metal such as magnesium. After austenitizing, oxidation is carried out by exposing the hot sample to a stream of compressed air for a period of 30 to 60 sec. at temperatures below 1740° F., or for 10 to 30 sec. at higher temperatures. The sample, which is polished before treatment, is quenched and repolished. Polishing demands care since the hard surface oxide film must be removed without destroying the thin underlayer. With experience, however, good results can be obtained without difficulty. The polished sample is etched in Vilella's reagent (1 g. picric acid, 5 ml. hydrochloric acid, 100 ml. ethyl alcohol) or in Benedicks' reagent (5% metanitro-benzole-sulphonic acid in ethyl alcohol) or, in a 15% alcoholic solution of hydrochloric acid.

It is found that the austenitic grain size revealed in this way is usually about 3 units smaller on the A.S.T.M. scale than that obtained by the carburizing method. In view of the wide acceptance of the A.S.T.M. procedure, it is suggested that the customary grain size index may be read directly by examining the polished sample under a suitably higher magnification, that is 283 × instead of 100 ×.

Practical experience in examining over 100 specimens by this "oxidation-after-austenitizing" treatment disclosed uneven oxidation in large samples, which led to difficulty in uniform polishing, but it was soon found that sufficiently large portions of the sample had been correctly polished and gave a clear measure of grain size.

The non-uniform grain size found in banded structures in mild steel, and rarely exposed satisfactorily by

*(Continued on p. 162)*

## Grain Size . . .

the A.S.T.M. test, was well revealed by the oxidation technique.

It is recognized that it is very difficult in practice to austentize in the complete absence of oxygen. Nevertheless, it is very probable that the amount of interference with the austenitizing process is substantially less than in the A.S.T.M. procedure, and the fact that the grain size consistently appears to be smaller by about 3 A.S.T.M. numbers provides strong confirmation.

C. B. LANDER

## Aluminum-Tin Bearing Alloys*

The unique qualities of aluminum-base bearing alloys have been appreciated by many engineers but poor bonding qualities and tendency to score unhardened steel journals have prevented the general application of these alloys. General Motors on this side and the Tin Research Committee in England are carrying on applied research that aims to remove these objections. Under the aegis of the latter, Cuthbertson and Ellwood have carried on a careful study of the aluminum-tin bearing alloys, with and without the addition of 1% copper. In their opinion, tin-base babbitts are probably the most satisfactory for loads up to 2500 psi. At higher loads, however, babbitt is apt to fail by fatigue. Copper-base alloys (if the term alloy may be used in this connection) were the next to be considered and now it looks as though aluminum with tin between 15 and 30% and with 1% copper may meet the requirements of the engineer including that of bonding to steel backings, good fatigue resistance and freedom from scoring.

The aluminum-tin equilibrium diagram indicates a very low solubility (about 0.50%) for tin in aluminum. Primary crystals of almost pure aluminum first separate out during the solidification of these alloys, with the result that these crys-

*(Continued on p. 164)*

*Digest of "Improvement of Aluminum-Tin Bearing Alloys", by J. W. Cuthbertson and E. C. Ellwood, *Metal Industry*, Vol. 85, July 30, 1954, p. 83-86.


# How Stanley doubled steel strap capacity overnight . . . slashed fuel costs, too

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**Rear view of Kemp Pot at Stanley Works shows gas feed lines, fire checks, and the Kemp Carburetor (left). Part of every Kemp Installation, this carburetor assures complete combustion . . . without waste . . . without tinkering. Just set it, and forget it.**

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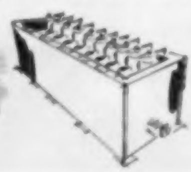

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## Bearing Alloys . . .

tals are surrounded by tin which freezes last. In alloys having 5% tin, the tin is not a continuous phase and the maximum tensile strength and elongation are realized. At 10% tin and higher the elongation falls very rapidly, especially as the temperature of testing is raised. The remedy is to alter the distribution of the tin. One way to do this is to control the casting conditions. With this method the formation of a continuous phase is retarded for alloys up to 15% tin, and even up to 20% tin if copper is added.

Another and better method is to change the structure by cold forging and recrystallization heat treatment. Its advantages are that the tin content is not limited and control need not be as precise. The forged alloy is annealed at 660° F. to recrystallize the aluminum and redistribute the tin. If the forging (cold) is carried to at least 20% reduction there is a complete disruption of tin films and to some extent the tin is spheroidized. The elongation for alloys modified in this way will increase as the temperature of testing is raised, whereas it decreases in the unmodified cast alloys. This is true for tin contents up to 40%. The copper addition goes into solution in the aluminum, which it hardens, while leaving the tin unaltered. One percent of copper is the amount considered best. The desired combination of softness with high fatigue strength is found to a greater degree in the aluminum-tin-copper alloy than in the other bearing alloys of the group.

The fatigue testing machine preferred by the authors is that designed by Dr. Underwood of the General Motors Corp. Any alloy used as an unbacked bearing will have a lower fatigue life than one of extreme thinness but bonded to steel or bronze. Babbitt bonded to steel gave a fatigue life on the Underwood machine of 6 hr.; copper-lead, 8 hr.; aluminum-tin-copper with 30% tin and 1% copper failed only at 23 hr.; when the tin was reduced to 15% and copper raised to 3% it failed in 51½ hr. The rate of wear of the journals appeared similar for all bearing alloys. Plastic cements were used in bonding babbitt to steel backing but these be-

*(Continued on p. 166)*

## Bearing Alloys . . .

came brittle upon aging and their low heat conductivity increased the running temperature of the bearing.

Considerable comment is devoted to the bonding of aluminum alloy to steel. Casting methods suffer from the formation of a thick brittle layer resulting from the reaction between tin and iron. Problems encountered in attempts to make a bond by rolling are mentioned. The final result is, to quote verbatim: "Bonding below 232° C. leads to no practical loss of tin and eliminates the trouble of tin segregation which develops when the bonding takes place above 232° C. Bonding in this way appears to be entirely practicable. Numerous tests on the Underwood machine made by this procedure have given most encouraging results, there being no evidence of bond failure." Aluminum-tin alloys have been satisfactorily bonded to duralumin. As a precaution against seizing during the initial stages of using the aluminum-tin-copper alloy, the bearing should be immersed for a few seconds in a hot sodium stannate solution to produce a smear of tin for temporary lubrication.

Harold J. Roast

## Effect of Temperature on Corrosion of Aluminum*

Tests were made on commercial aluminum (0.13% Si, 0.43% Fe), duralumin (0.105 Si, 1.08 Fe, 3.52 Cu, 1.32 Mg, 0.52 Mn, bal. Al), and magnalium (0.43 Si, 0.08 Fe, 2.02 Mg, 0.32 Mn, trace of Cu, bal. Al). The specimens were 0.25-in. rods 0.40 in. long. No special heat treatment was used. The specimens were cleaned with a file, polished on felt with aluminum oxide powders No. 28, 20 and 10, washed with distilled water, degreased with acetone, washed with alcohol, and then kept in a desiccator for 16 to 18 hr. prior to testing.

*(Continued on p. 168)*

*Digest of "Influence of Temperature on the Rate of Corrosion of Aluminum and Several Aluminum Alloys", by G. V. Akimov and V. V. Romanov, *Doklady Akademii Nauk SSSR*, Vol. 91, 1953, p. 281-283.

## Corrosion of Al . . .

The specimens were corroded by solutions 1 *N* in chloride ion and of pH values of 1, 3, 6, 11 and 13 at temperatures of 32, 68, 120, and 175° F. The volume of the electrolyte was 300 cc., the ratio of this volume to the surface of a specimen being 830, which gives a maximum rate of corrosion for commercial aluminum. The time of testing was 5 hr., except that 10 hr. was used for the neutral solution. At the end of a test the specimen was carefully washed in water and then cleaned for 30 to 40 min. in a solution of 6% nitric acid and 1% potassium dichromate to remove the products of corrosion. A control specimen was used during this operation. The specimen was then washed in water, dried using acetone and alcohol, and weighed on a microbalance with a sensitivity of ± 0.01 mg.

In the accompanying graphs each plotted point is the average of 4 to 8 determinations. Figure 1 gives the corrosion rates of aluminum and the two alloys in neutral 1 *N* sodium chloride and shows a maximum at 120° F. The surface of the aluminum was not much changed in this solution.

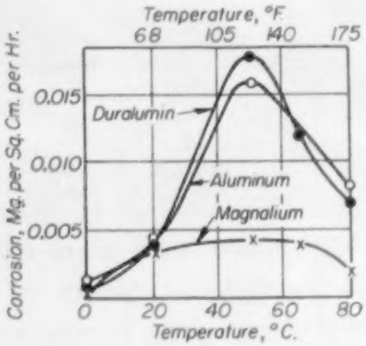


*Fig. 1 – Influence of Temperature on Corrosion Rates in 1 N Solution of Sodium Chloride, pH 6*

Figure 2 shows that the corrosion rate for aluminum and duralumin in an acid chloride solution of pH 3 increased rapidly with increasing temperature. The brightness of the surface of both materials also increased. At 175° F. the bright surface of the duralumin was completely covered with tiny pits while the aluminum was free from such visible

*(Continued on p. 170)*


This Westinghouse induction heating machine uses highly efficient, sideways feed method pioneered by Westinghouse. Occupying only 15 sq ft, it delivers 1⅝" square by 14" billets, heated to 2300° F, at a rate of 260 per hour.

# FACT:

## This completely automatic billet heater cuts forging costs . . . ups production

**These specific advantages tell why:**

**Scale Loss**—0.6% is typical—60 to 80% less than other heating methods, *because* the speed and precision of Westinghouse induction heating doesn't give scale a chance to form.

**Maintenance Costs**—80% reduction is not at all unusual, *because* Westinghouse design gives you high availability—minimizes maintenance labor costs.

**Down-Time Production Loss**—Extremely low down time of Westinghouse induction heating equipment compared with other heating methods means less lost production.

**Labor Costs**—50% savings are not at all unusual, *because* Westinghouse automatic equipment eliminates handling operations.

**Other Advantages**, including significant space savings; cool, clean working conditions; quick start-up and very low stand-by losses, combine to make Westinghouse induction heating your best investment in advanced, lowest cost billet heating.

For sound advice on reducing *your* forging costs, call The Man With The Facts—your Westinghouse sales engineer. And—ask him for your copy of booklet B-6519, or write Westinghouse Electric Corporation, 3 Gateway Center, Pittsburgh 30, Pennsylvania.

J-02295

YOU CAN BE **SURE**...IF IT'S

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## Corrosion of Al . . .

traces of corrosion at all temperatures. In a more acid solution of pH 1 the corrosion rates increased even more rapidly with temperature. An anomaly was observed in the corrosion of aluminum by this solution

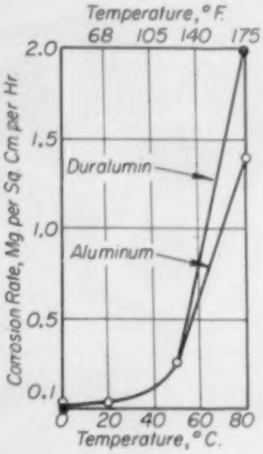



*Fig. 2 — Influence of Temperature on Corrosion Rates in a Sodium Chloride, Hydrochloric Acid Solution 1 N in Chloride Ion, pH 3*

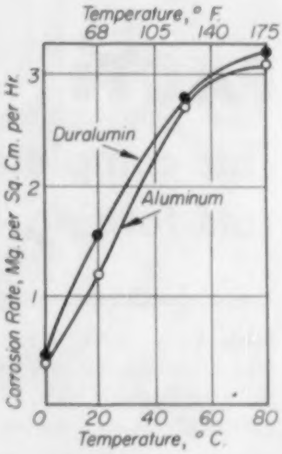
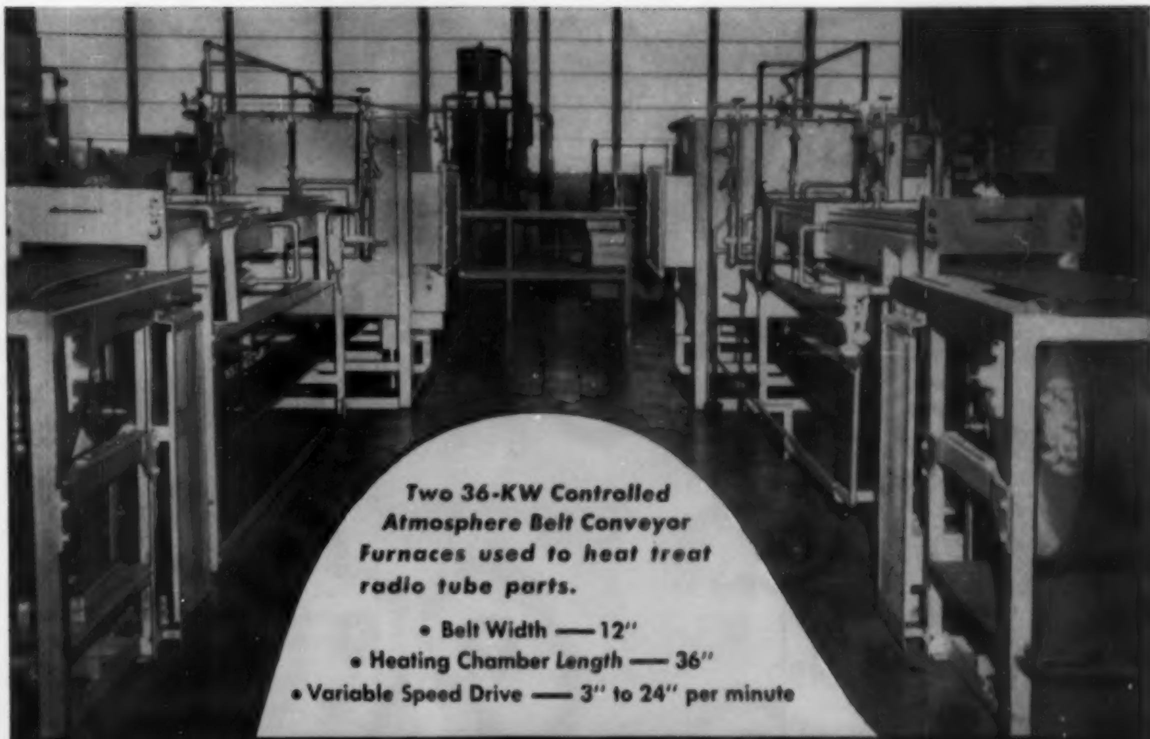



*Fig. 3 — Influence of Temperature on the Corrosion Rates in a Sodium Chloride, Sodium Hydroxide Solution 1 N in Chloride Ion, pH 11*

at 120° F., it being faster (by a factor of ten) than the duralumin.

Figure 3 gives the corrosion rates of aluminum and duralumin in an alkaline chloride solution of pH 11. The corrosion rates increased by less

*(Continued on p. 172)*

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## Corrosion of Al . . .

than a factor of ten over the entire range of temperatures studied. Both specimens became covered with a dark film – copper-brown at 32 to 68° F. and a darker color at higher temperatures. After this corrosion product was removed the surface was bright. Small pits appeared on the surface at 68° F., while at 175° F. the pits were deeper and larger. In a more alkaline solution of pH 13 the corrosion rate sharply increased with increase in temperature. At 32 and 68° F. the corrosion rate of aluminum was slower, while at higher temperatures it was faster than that of duralumin. In this solution the corrosion film, which was friable and easily removed from the specimen, was dark brown at 32° F. and completely black at higher temperatures. Corrosion was more uniform in this solution than at pH 11.

A. G. Guy

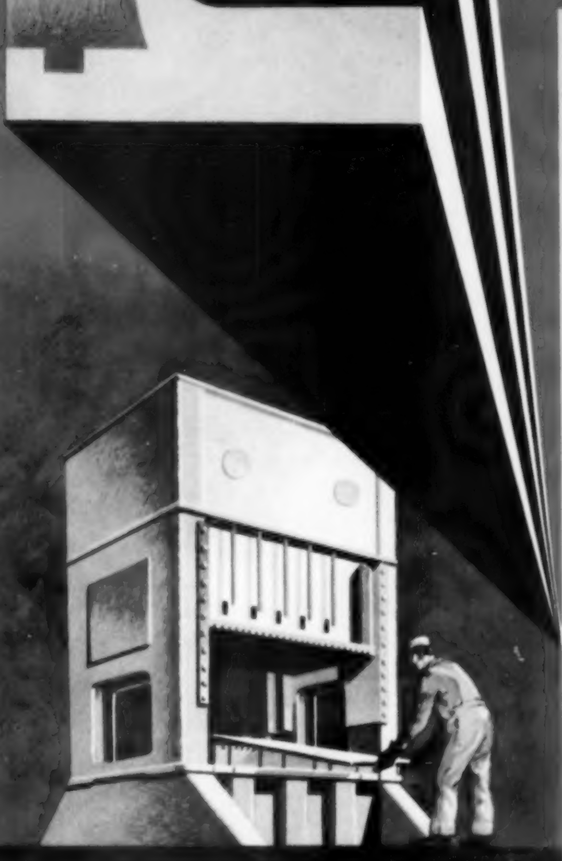
## Fine-Grained Cast Copper Alloys*

An old foundry adage, "the finer the grain, the better the metal", is finding scientific support. This being so, the question arises "How do we refine the grain?" The applied research recorded by Cibula goes a long way in supplying data to enable the metallurgist to refine the grain of the copper-base alloys. The writer had found in his work on light alloys that refinement was produced by the introduction of fine particles that would act as nuclei during solidification. It seemed desirable that the compound used should have a lattice structure similar to the crystals to be refined. This pointed to the nitrides, carbides or borides of several transition metals.

Seven-kilogram melts of phosphorus-deoxidized bronzes and gun metals were made in alumina-coated Salamander crucibles in a gas-fired injector furnace. The copper was melted under a slightly oxidizing flame and, except in special cases, no other degassing treatment

*(Continued on p. 174)*

***Digest of "Grain Refining Additions for Cast Copper Alloys", by A. Cibula, *Journal* of the Institute of Metals, Vol. 82, July 1954, p. 513-523.**



## Two Steels Are Fused By Jessop Skill To Bring You Better Dies At Lower Cost

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# Rush Stamping Company gives stamp of approval to Cities Service

**Some of Rush's Stampings** awaiting shipment. The rapidly growing, 4½ year old firm makes parts for auto hot water heaters, brake levers, vacuum cleaners, and air conditioning units.

**Chief Engineer Fred W. Selter** switched to Cities Service drawing oil a year ago. He praises it for eliminating need for many compounds, preventing build-up on dies, and lowering costs.

**Praises Cities Service drawing oil as timesaver, worksaver, moneysaver.**

The four and a half year old Rush Stamping Company of Toledo, Ohio, has already grown into a sizeable operation. Producing stampings for air conditioning units, vacuum cleaners and automotive parts, the company utilizes 41 punch presses ranging from 35 to 400 tons in pressure.

Like many other stamping companies, Rush was using a variety of paste type compounds for its drawing operations and suffering the penalty of heavy costs and build-up on dies which such compounds inflict. Then, a year ago, they switched to Cities Service drawing oil.

Here are the results in the words of F. W. Selter, Chief Engineer: "Now one Cities Service Oil does our variety of jobs, completely eliminating previous number of products and compounds required. This oil prevents build-up on dies formerly created by our paste type compounds, and in some applications saves as much as 50% in costs over these compounds. In addition, Cities Service has eliminated supply problems by offering us local warehousing and engineering services."

Learn more about Cities Service drawing oils which have already received the stamp of approval from so many firms. Talk with a Cities Service Lubrication Engineer. Or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.

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## Copper Alloys . . .

was used. After the main alloying metals had been added, the melt was deoxidized with 0.03% phosphorus, the nucleating compound was added and the metal was cast into 4-in. long rods ⅝ or 2⅜ in. diameter in green sand molds. The feeder heads used for these two sizes measured 1⅜ in. diameter by 1⅛ in. and 3⅜ in. diameter by 3 in., respectively.

Discussion is given of previous work done, one conclusion being: "Where the initial solid differs greatly from the melt in composition, a layer of low-melting-point liquid forms around the first dendrites, owing to incomplete diffusion, and hinders their further growth; it has been suggested that the effect of the solute-rich barrier is reinforced in some alloys by the precipitation of a second phase around the dendrites. However, although this or a similar mechanism may produce equiaxial instead of columnar structures, the grain size remains large." The refinement in grain obtained by pouring ingots at a low temperature is mentioned; however, in the work under discussion, the casting temperatures used were high enough to eliminate this as a factor.

Carbides, nitrides and borides (including aluminum diboride) were used as grain refiners in copper alloys. The article contains a tabulation of 22 of the most suitable nucleating compounds for copper-base alloys, and another of the composition and preparation of the 14 nucleating alloys used. It was found that the borides could be precipitated as small crystals in the melt by adding master alloys of boron and the transition metals. The addition of carbides (and nitrides) was less straightforward, and the following methods were tried:

1. A copper-titanium (26%) alloy containing 1.5% titanium carbide (prepared by dissolving titanium in copper under a charcoal cover) was added to the melts just before casting.

2. Pellets of titanium carbide, bonded with 20 to 66% nickel by sintering in vacuum at 2550° F., were added to the melts.

3. Carbon was dissolved in the melts by heating them under charcoal or in contact with graphite be-

(Continued on p. 176)

## Copper Alloys . . .

fore the addition of titanium or zirconium.

Each method was effective in reducing grain size, but the first and second were objectionable because high temperature and excessive amounts of transition metal were needed. The third method was the one used. For the purposes of examination, transverse sections taken from the middle of the bars were etched with alcoholic ferric chloride. The grain sizes were measured to ± 25% with a rule, at a convenient magnification at points half-way along the radii. Sections for microexamination were taken from the ⅝-in. diameter test bars, next to the surface prepared for grain size estimation. The use of diamond dust was found to be essential for polishing these specimens owing to the hardness of the boride and carbide crystals. (Abstractor's Note: This suggests that trouble might be encountered in machining castings made from such metal.)

Of the numerous compounds used, zirconium and titanium carbides were very effective. Zirconium between 0.02 and 0.03% gave the maximum effect, providing carbon was in intimate contact with the melt during and after oxidation. Nitrogen acts in a similar manner to carbon, although to a less degree. Sulphur to the extent of 0.3% was found to entirely prevent grain refining but the addition of magnesium nullifies this effect. Boron alone had no effect on grain size but greatly increased the grain refinement of the transition metals.

The greatest refinement was found when 0.03% boron (0.01% boron actually left in the melt) was used with 0.1 to 0.3% of iron or cobalt. An addition of boron with 0.05% columbium resulted in as much grain refinement as that by titanium boride. The grain refinement of zirconium with boron, although marked, was less than that produced by zirconium additions with carbon but no boron. Numerous tests were made on many combinations, both of primary alloying elements and nucleating compounds.

Various charts are given summarizing the data obtained. Attention is drawn to the fact that since con-

*(Continued on p. 178)*

## Copper Alloys . . .

siderable turbulance is produced in the making of castings, it is not desirable that tenacious oxide skins be present. However, with zirconium at 0.03%, titanium at 0.1%, iron at 0.2% and cobalt at 0.5% – all effective amounts for the purpose of grain refinement – the oxide films were no more tenacious than zinc oxide in gun metal. The cost of the grain-refinement additions is given as between 30 and 90c per 100 lb.

H. J. Roast

## High-Resolution Replicas*

One of the oldest replica methods of electron metallography, the two-stage plastic impression and evaporated silica technique, has been improved by using evaporated carbon in place of silica (silicon dioxide). The advantages of using carbon rather than silica films are mainly of a practical nature, although some differences in properties do exist. Carbon replica films formed by vacuum evaporation are easier to prepare and handle than corresponding silica films because of their greater strength and ductility. Also, their brown color makes them readily visible. The strength and conductivity of evaporated carbon give the replicas great stability under electron bombardment in the electron microscope, making it possible to use extremely thin replicas to improve resolution. Carbon films are amorphous and a resolution of better than 50 Angstrom units in electron metallographic examination of metallurgical specimens is claimed possible, this improvement being attributed to the absence of the usual limitation resulting from the structure of the replica itself.

The first step in the carbon replica method, following suitable polishing and etching, is preparation of a negative plastic impression of the specimen surface. Instead of molding a thermoplastic against the specimen

*(Continued on p. 180)*

*Digest of "A High-Resolution Evaporated-Carbon Replica Technique for the Electron Microscope", by D. E. Bradley, *Journal* of the Institute of Metals, Vol. 83, 1954-55, p. 35-38.

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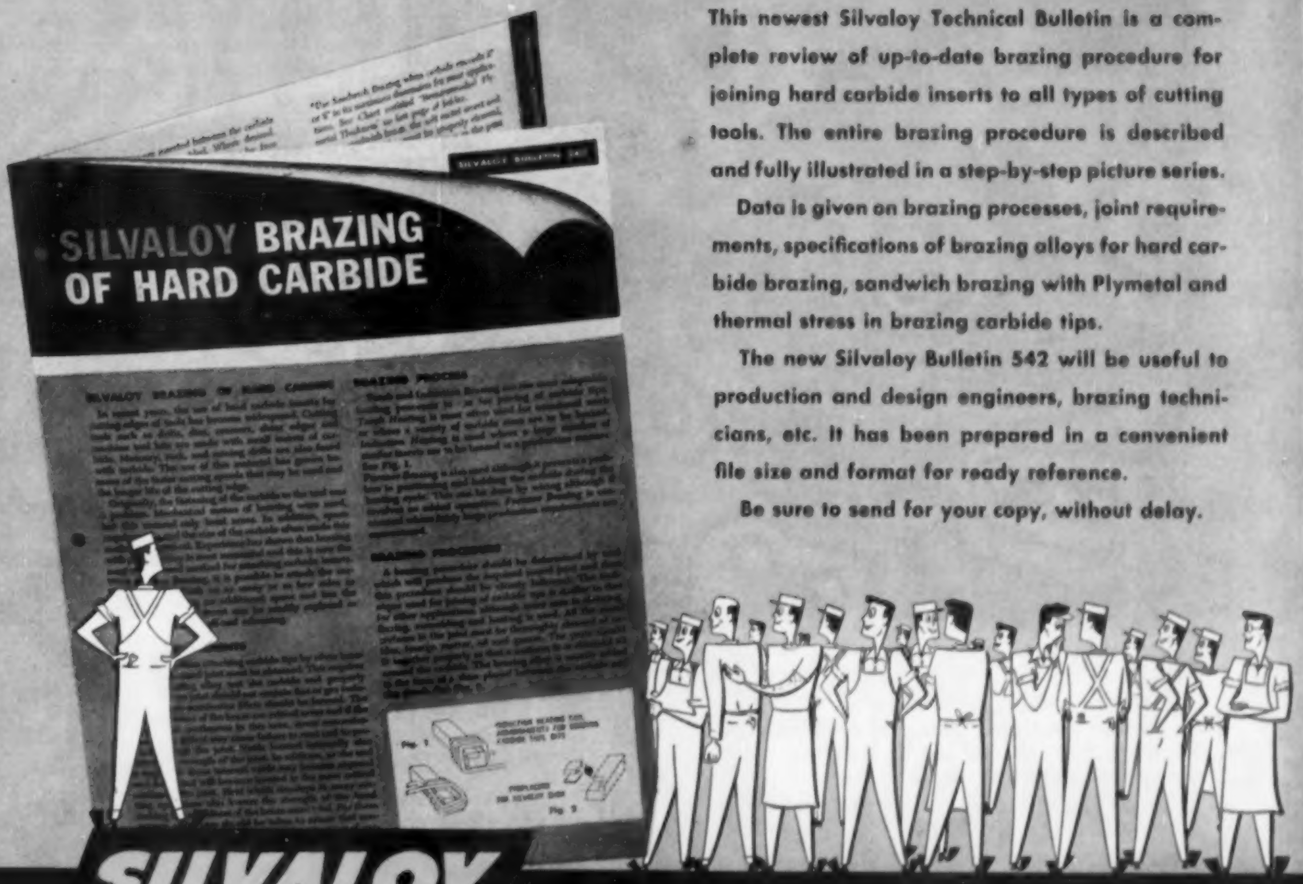


This newest Silvaloy Technical Bulletin is a complete review of up-to-date brazing procedure for joining hard carbide inserts to all types of cutting tools. The entire brazing procedure is described and fully illustrated in a step-by-step picture series.

Data is given on brazing processes, joint requirements, specifications of brazing alloys for hard carbide brazing, sandwich brazing with Plymetal and thermal stress in brazing carbide tips.

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## Replicas . . .

surface, as in the original two-stage technique, a cast impression is made by flooding the surface of the specimen, which is held vertically, with a dilute (1 to 2%) solution of Formvar in chloroform. A thicker layer of another plastic, Bedacryl, is similarly formed over the dried Formvar film using a more concentrated solution (7%) of Bedacryl in benzene. When this backing layer has hardened thoroughly the composite film is stripped from the surface with cellophane tape. This whole procedure is essentially the same as that commonly used for preparation of single-step negative plastic replicas.

The carbon replica film is produced by coating the Formvar with carbon by vacuum evaporation. Pointed spectroscopic graphite rods are pressed together with light springs*, and current of 20 to 30 amp., supplied from a step-down transformer, causes local heating at the points sufficient for carbon evaporation. The condensed carbon film is brown in color and its thickness can be judged from the depth of the color. Very light brown indicates a thickness of 50 A. and a dark brown color corresponds to about 300 A. To avoid self-shadowing, the carbon should be deposited normal to the replica surface.

The Formvar replica film and Bedacryl backing layer must be removed with solvents and the carbon replica mounted on a small disk of supporting mesh for examination in the electron microscope. To aid in interpretation of carbon replicas it is often desirable to shadow-cast the replica (oblique vacuum metallizing) with a heavy metal such as uranium or palladium. To do this it is necessary to keep track of the replicating surface of the carbon film in mounting so that shadowing metal is deposited on the proper surface. The author describes several mounting procedures for both shadowed and unshadowed replicas.

Illustrations are shown of unshadowed and gold-palladium-shadowed carbon replicas of coarse

*(Continued on p. 182)*

*Ernest F. Fullam, Inc., Schenectady, N.Y., and Optical Film Engineering Co., Philadelphia, supply kits of materials and instructions for modifying most evaporating units to make carbon replicas.

# Tool Steel Topics

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

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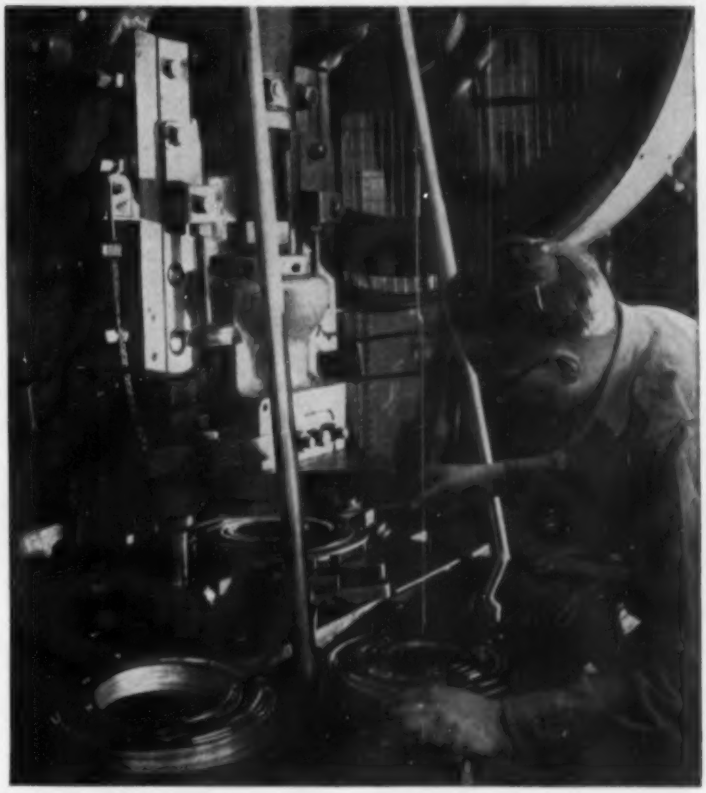
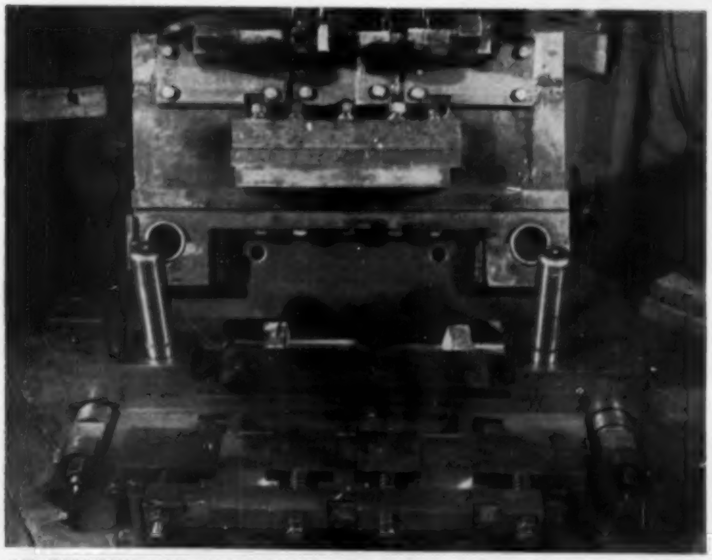
## 600 Stovepipe Shields Turned Out per Hour with BTR Hollow-Bar Die



In a blanking and forming operation, the Par Machine & Engineering Co., Brooklyn, uses this 58-ton press to make stovepipe shields from chrome-plated 0.015-in. steel. The die, made from five separate pieces of BTR (Bethlehem Tool Room) Hollow-Bar, is hardened to Rockwell C 60-61. It is interchangeable so that four inside diameters can be blanked and formed, and turns out as many as 600 pieces per hour.

BTR Hollow-Bar is made from our oil-hardening tool steel by a process called high-speed trepanning. With this method, hammer-forged round bars are cored out in the center, and are then rough-turned on the outside.

BTR Hollow-Bar makes it unnecessary for you to lose valuable time waiting for forged rings or discs. And there's no drilling, rough-boring, rough-facing or rough-turning required! For full information about BTR Hollow-Bar, just get in touch with your tool-steel distributor.



### 67 CHISEL DIE MAKES 14,000 CUTS BETWEEN GRINDS

Here's a die that's giving a good account of itself producing ends for expanded steel joists. Made of Bethlehem 67 Chisel, it blanks approximately 14,000 I-beam sections, varying in thickness from 3/16 in. to 3/8 in., before redressing is required. 67 Chisel, our chrome-tungsten shock-resisting steel, has good wear-resistance. Moreover, it is an easy steel to machine and heat-treat.

## BETHLEHEM TOOL STEEL ENGINEER SAYS:

### *How to "Blue" Hot-Work Tools*

Regardless of the lubricant used in hot-work tools, operators of such tools are continually searching for improvement. For "pickup" of metal on the tools, though a serious problem, can be minimized by good lubrication.

"Bluing" hot-work tool surfaces is a procedure which will aid the normal lubricating procedure on virtually every type of hot-work tool. As most tools of this type are ordinarily double-tempered, "bluing" can be accomplished with no expense or delay by following this heat-treatment procedure:

1. Quench tools in customary manner.
2. Temper tools as usual, to desired hardness.
3. Grind to finished dimensions.
4. Retemper at 1000 F, or higher. Temperature should be 50 F lower than the first temper. Thus the second temper serves as the "bluing" operation.
5. Tool can be placed in service without further operations on its dark, discolored surface.

Here's something else to keep in mind: when hot-work tools are redressed, it is also wise to retemper them not only for stress-relief, but also to obtain the "bluing."

## Replicas . . .

pearlite. Both the appearance and interpretation of the unshadowed replicas are similar to that of a silicon replica with contrast in the replica resulting only from changes in surface contour. The shadowed replica is more easily interpreted in terms of the original surface relief since the two-stage replica has the same relief as the original etched specimen and the cementite lamellae appear to project up from the surface of the specimen. Because of their stability, carbon replicas are ideally suited for stereoscopy of surfaces having a great deal of relief.

Micrographs are shown of an age hardened copper-beryllium alloy of 97.5% copper, 2% beryllium and 0.5% cobalt. Also included in the paper is an electron micrograph at very high magnification (200,000 ×) of an unshadowed carbon replica of a tempered steel. Fine detail of 50 A. or less can be seen in this micrograph. It is stated that the Formvar replica reproduces the surface detail with good fidelity and that the one-step Formvar replica is limited in resolution only because it is not a suitable type of replica for use in the electron microscope. Thus, evaporated carbon copies can be expected to show finer detail than the original Formvar impression.

R. M. Fisher

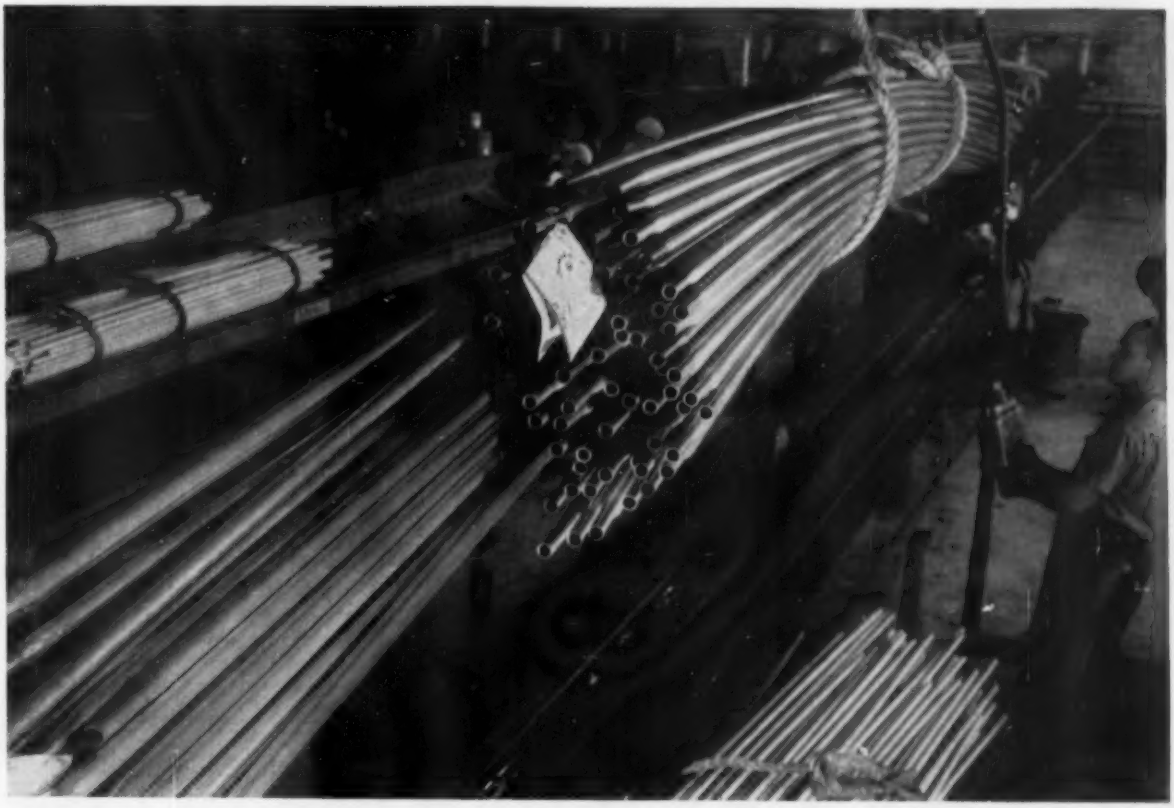
## Creep Lifetime of Aluminum Columns*

Because of the increasing use of elevated temperatures, knowledge of the creep behavior of structural elements has become very important, particularly in the development of supersonic aircraft and missiles. In this investigation the results of static-strength and creep tests of small 7075-T 6 (75 S-T 6) aluminum alloy columns were studied to determine procedures for predicting column lifetime.

Fifty-four columns with a nominal

(*Continued on p. 184*)

*Digest of "An Investigation of the Creep Lifetime of 75S-T6 Aluminum-Alloy Columns", by E. E. Mathauser and W. A. Brooks, Jr., Technical Note 3204, National Advisory Committee for Aeronautics, July 1954.



# Good News about Titanium!

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**Superior Tube**

**The big name in small tubing**

All analyses .010″ to ⅝″ O.D. Certain analyses in light walls up to 2½″ O.D.

## Creep Lifetime . . .

cross section of ⅜ in. by ⅛ in. were tested at temperatures of 300, 400, 500 and 600° F. in a dead-weight apparatus to determine their creep-strength lifetime. The members tested had slenderness ratios between 29 and 110, and out-of-straightnesses at mid-height of approximately 0.002 to 0.04 times the thickness of the member. The specimens were exposed to the test temperature for 30 min., after which the load was applied at a rate requiring about 20 sec. to bring the total load to bear. The lifetimes, measured from the beginning of loading, ranged from several minutes to a few hours. Other similar members were tested statically at the same temperatures to determine maximum critical loads. The results of these latter tests are in good agreement with the tangent modulus and Euler stresses.

It was found that creep specimens collapsed fairly rapidly after a critical deflection was reached. For columns with slenderness ratios of less than 100, this critical deflection was less than 75% of the column thickness. In view of this, analyses based on small deflection theory are reasonable and are not usually subject to any appreciable error up to the beginning of collapse of the column. The most significant data obtained from the tests are the lifetimes corresponding to different slenderness ratios and various stress levels at each temperature. The tangent-modulus stress is the maximum stress that a column can support; this stress implies zero column lifetime. The results reveal that for short-time creep tests, low stress ratios are associated with short, inelastic columns and high stress ratios with long elastic columns.

The test data are compared with results of an approximate theoretical solution that generally predicts lifetimes smaller than those obtained in the tests. This discrepancy is ascribed to assumptions made in the theoretical analysis. For example, the initial deflected shape was assumed to be sinusoidal so that equilibrium and compatibility needed to be satisfied only at mid-height. In the analysis, the magnitude of the creep strain on the concave side of the member is used as a criterion for

*(Continued on p. 186)*

## Creep Lifetime . . .

column lifetime; therefore the predicted lifetime is low, particularly for short or inelastic columns.

Semi-empirical lifetime curves are obtained by fitting curves with the shape predicted by the theory to the test data. These curves make it possible to predict column lifetimes for values of stress and out-of-straightness not covered in the tests. It is shown that the lifetime may change considerably due to a small change in average stress but that it is only very slightly affected by a small change in out-of-straightness. The lifetime of a long column is more affected by changes in average stress or out-of-straightness than is that of a short column. Since lifetime is only slightly influenced by out-of-straightness, data can be presented in the form of stress-lifetime or stress-temperature-lifetime plots which do not explicitly include the out-of-straightness. In the latter form, the use of an empirical time-temperature parameter permits all data to be presented in one graph. Often the out-of-straightness is not known, so that this type of plot is convenient for use for design purposes.

J. G. SUTHERLAND

## Oxidation Studies of Al-Mg Alloys*

THIS research was evidently prompted by the fact that the addition of magnesium to aluminum, even when only 0.5% was added, causes a metal-mold reaction which produces a surface discoloration and gas porosity. The addition of as little as 0.0001% beryllium was confirmed as having a definite preventive action regarding discoloration and gas porosity of the base metal (alumium with 10% magnesium, both of the highest purity). An addition of 0.004% beryllium was found to give the best protection, whereas 0.025%

*(Continued on p. 188)*

*Digest of "The Oxidation of Aluminium-Magnesium Alloys by Steam: a Contribution to Research on Mold Reaction", by Marjorie Whitaker; and "The Constitution of Oxide Films Formed at High Temperature on Aluminium-Magnesium Alloys", by A. R. Heath, *Journal of the Institute of Metals*, Vol. 82, 1953-54, p. 107-115.

## Oxidation Studies . . .

did not give as good results either in the laboratory or the foundry test.

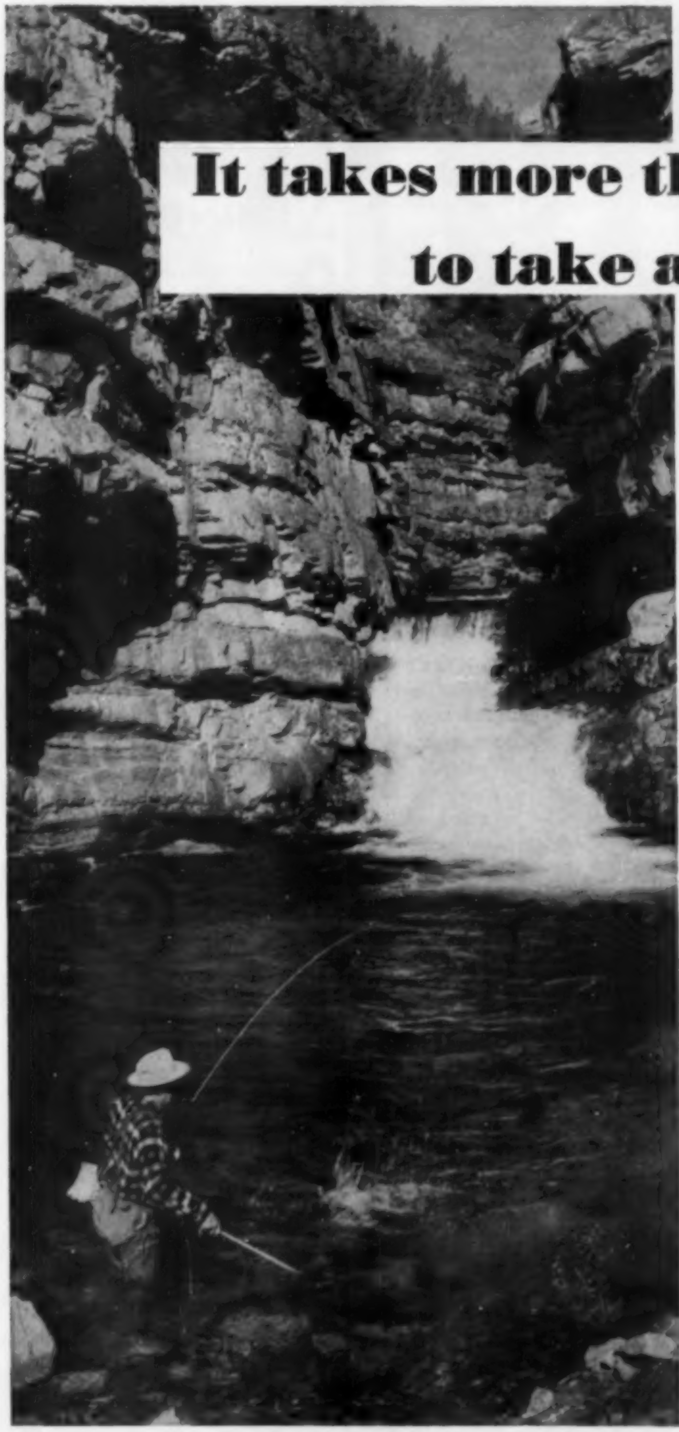
The laboratory tests were conducted as follows: Cylindrical specimens 5 cm. long and 1 cm. diameter were machined dry from the as-cast alloy, and drilled so as to leave a wall thickness of about 3 mm. A thermocouple was inserted half way in the length, with the thermocouple supporting the cylinder in a containing tube so that the steam flowing through the latter could come into intimate contact with the specimen. A temperature of 580° C. (1075° F.) was maintained for 15-min. intervals by means of induction heating.

The increase in weight of the specimens after the test was taken as the measure of oxidation and gas absorption. The 18 specimens tested had a beryllium content between 0.0001 and 0.15%. Degassing of the melt had no practical effect.

For the second series of tests, 24 specimens were made which would show the effect of elements such as iron, silicon, copper, calcium, sodium and potassium, as well as of the grain-refining agents titanium and boron. The beryllium content in these ranged from 0.003 to 0.004%. No significant difference was noted in any of these tests, except for sodium which almost completely nullified the benefit of beryllium. Carbon available from the hexachlorethane, which was used as a degassing agent, had no adverse effect.

For the third series of tests, 36 alloys were made up in three groups varying in cerium, columbium, tantalum, thorium, vanadium and zirconium. With the first group no beryllium was added, the second had 0.004% beryllium, and the third 0.04% beryllium. All six elements had a slight inhibiting effect but much less than beryllium. Taken in conjunction with a series of supporting foundry tests, the evidence was that nothing was to be gained by any of these additions to alloys containing beryllium. The work recorded in the Appendix by Heath gave no evidence that the oxide formed was an amorphic layer of beryllia but rather suggests that the film consists of a multi-phase layer containing magnesia, beryllia, and possibly a third complex.

H. J. Roast



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# Procedures for Silver Brazing of Refractory Metals*

SILVER brazing alloys are, under standard brazing procedures, suited to joining nearly all metals. The principal exceptions are aluminum and magnesium-base alloys, alloys that melt below the brazing temperature, and a number of other metals and alloys or combinations for which some modification of procedure is needed. The latter group includes aluminum bronze, beryllium copper, 17-7 precipitation hardening stainless steel, chromium stainless steel, chromium carbides, molybdenum, titanium, zirconium, tantalum and aluminum-to-copper.

In this group three things may interfere with effective brazing: (*a*) oxide films, which prevent surface wetting by the brazing alloy; (*b*) imcompatibility of the brazing alloy with the metals involved; (*c*) conflict with subsequent heat treatment, as in the brazing of precipitation hardening refractory alloys.

**Aluminum Bronze** – The standard flux for silver brazing (boric acid, alkaline borates and fluorides) is unsatisfactory because it leaves a black residue on the surface of the bronze. This residue prevents wetting and free flow of the brazing alloy. Addition of 15% zinc chloride to the flux solves the problem. In brazing aluminum bronze to steel, this flux addition destroys fluxing action on the steel. However, a flux mixture of borates, fluorides and chlorides is commercially available and will solve the problem.

Contamination of the brazing alloy with a small percentage of aluminum, resulting from solution of aluminum from the bronze and its diffusion through the alloy to the steel surface, will disrupt bonding to the steel if the brazing cycle is not kept as short as possible. This trouble can also be prevented by using a brazing alloy containing nickel. Another alternative is to place a copper shim in the joint to act as a barrier against diffusion of the aluminum to the steel. Copper

*(Continued on p. 192)*

*Digest of "Silver Brazing of Refractory Metals", by C. H. Chatfield, *Welding Journal*, Vol. 33, September 1954, p. 864-867.

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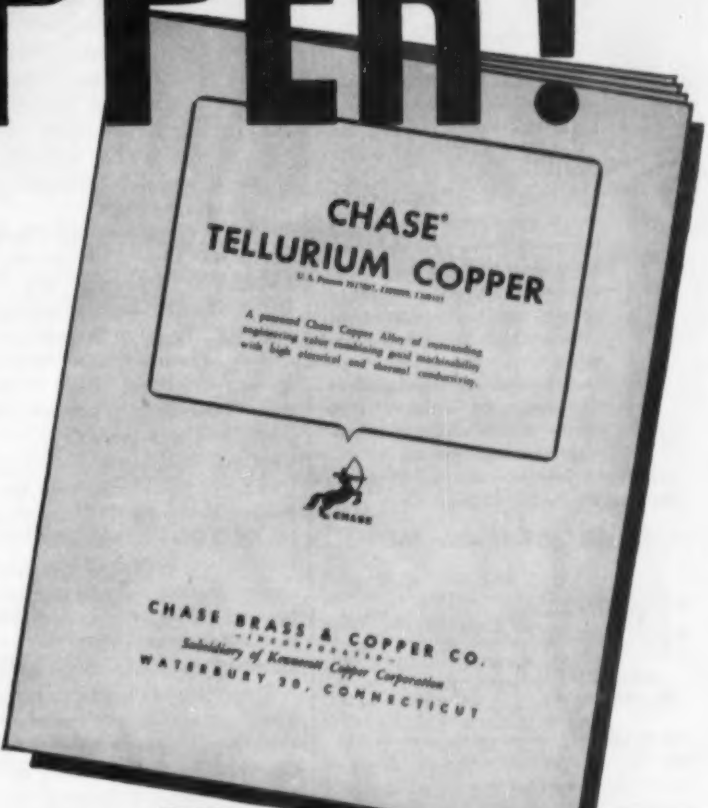


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Some degree of skill is required in the process because any flux entrapped in the joint will result in poor strength. Beryllium oxide is refractory, requiring an active flux to get maximum oxide solubility at the brazing temperature.

**17-7 Precipitation Hardening Stainless** – This is a precipitation hardenable steel that requires a transformation heat treatment at 1400° F. for 30 to 90 min., cooling to 60° F. and reheating to a range between 950 and 1050° F. for 90 min. A modified procedure, which gives excellent results, is to heat treat and cool at the specified temperatures, torch-braze with an alloy flowing below 1400° F., cool to 60° F. and finally reheat to 1050° F. The brazing cycle should be kept at minimum time. The transformation heat treatment and brazing also can be combined, provided the 1400° F. anneal is shortened to 30 min.

**Chromium carbides** present problems in wetting, particularly if, in some types, the nickel-rich surface has been ground off. Two methods are: (*a*) using a brazing alloy of Ag-Cu-Sn-Mn or (*b*) a flux containing 1% powdered silicon. Standard brazing alloys can be used with the latter flux. Another alternative is 85-15 Ag-Mn alloy with standard high-temperature flux.

**Chromium Stainless Steel** – The requisite in brazing these steels is not a strong joint but one which will resist corrosion in humid atmospheres. The answer appears to be the deposition of a nickel-rich layer

*(Continued on p. 194)*

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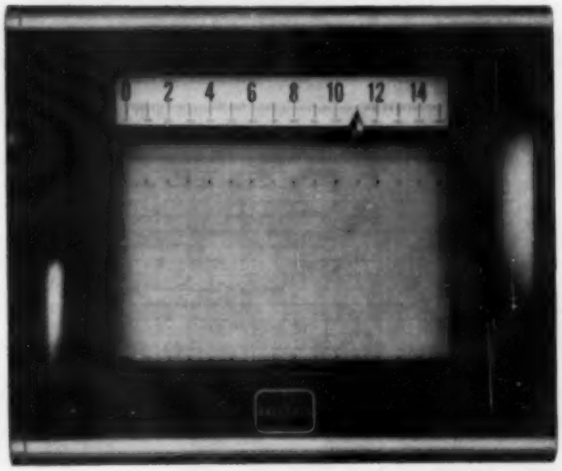

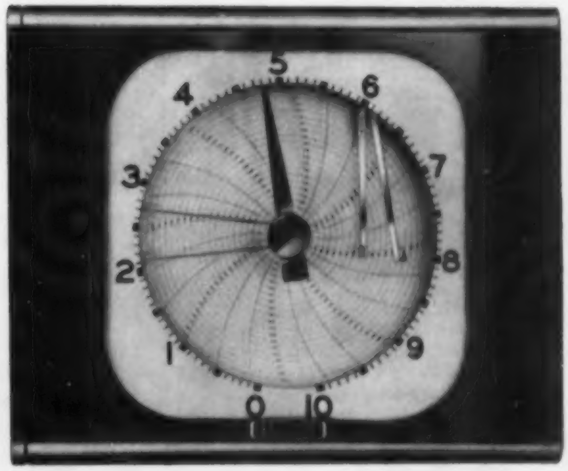

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## Silver Brazing . . .

from the brazing alloy. One alloy which will do this is 63% Ag, 28.5 Cu, 6 Sn, 2.5 Ni. Its only drawback is sluggishness and consequently poor spreading.

**Molybdenum** – Addition of phosphorus to the brazing alloy overcomes difficulties with this metal. As little as 0.25% produces marked improvement in surface wetting, but 1% is advisable for maximum joint strength. The phosphorus alloys are not recommended in brazing molybdenum alloys such as the M-2 high speed steels because brittle iron phosphide forms at the joint interface. An addition of about 5% of an alkali hydroxide to the conventional fluxes improves flow of the brazing alloy, although joint strengths will not be equal to those of the silver brazed tungsten high speed steels.

**Titanium and zirconium** act similarly in brazing, developing refractory oxides that are not easily removed by the flux and also forming brittle metallic compounds by reaction with the brazing alloy. A flux mixture of alkali metal chlorides and acid fluorides has been perfected to overcome the first drawback, while the second can be controlled to some extent by keeping time the metal is in contact with the molten brazing alloy at a minimum. Butt joints have been obtained on ⅜-in. titanium rod with average tensile strength of 45,000 psi.

**Tantalum** – Silver brazing alloys and the flux developed for titanium yield good results, although joints and base metal usually are brittle. Copper-gold alloys with less than 40% Au also have been used, but in any event there is likelihood of gas embrittlement of the tantalum.

**Aluminum-to-Copper** – Direct brazing with Al-Si alloys is unsatisfactory because of the low melting temperature and extreme brittleness of the Al-Cu eutectic. Strong and ductile joints have been made by tinning (0.005 in. minimum) the copper with a silver brazing alloy and then brazing to the aluminum with the Al-Si alloy. An alternative is brazing a sheet of silver to the copper. In brazing the silver-coated copper to aluminum, an aluminum brazing flux must be used to dissolve the refractory aluminum oxide film.

A. H. ALLEN

## Radioactive-Tracer Diffusion Studies*

Although Wells and Mehl determined the rate of diffusion of nickel in iron, the diffusion of iron in nickel had not previously been studied. In this investigation a radioactive-tracer method as devised by Kryukov and Zhukhovitskii was used. In this technique a thin layer of the diffusing metal is electroplated on the surface of a foil of the base metal, the intensities of radiation on the two sides of the foil are measured after diffusion, and the diffusion coefficient, assumed to be independent of concentration, is calculated from these measurements.

The nickel foil, 0.0017 in. thick, contained no more than 0.15% silicon, 0.02% manganese, 0.05% magnesium, and 0.005% sulphur. Iron-59 was the tracer element. Heating was done for 2 to 14 hr. in a quartz tube using a vacuum of $10^{-5}$ to $10^{-6}$ mm. with temperatures controlled to $\pm 4^\circ$ F. ($2^\circ$ C.). Values of the diffusion coefficient of iron in nickel determined at four different temperatures are given in the accompanying tabulation, together with the corresponding values of the coefficient for the diffusion of nickel in iron given by Wells and Mehl. The equation $D = D_0 e^{-Q/RT}$ for the diffusion of iron in nickel was found to be

| Temperature | Diffusion Coefficient† | |
|---|---|---|
| | Fe in Ni | Ni in Fe |
| 1745° F. | 6.9 | 0.3 |
| 1830 | 14.7 | 0.84 |
| 1931 | 31.4 | 2.58 |
| 2059 | 95.6 | 9.5 |

†Sq.cm. per sec. × $10^{11}$.

$$D = 0.0084\, e \frac{-51{,}000}{RT}$$

while Wells and Mehl reported

$$D = 0.344\, e \frac{-67{,}500}{RT}$$

for the diffusion of nickel in iron. Thus, the activation energy for the diffusion of iron in nickel is lower, and the diffusion rate is higher by more than a factor of ten.

A. G. Guy

*Digest of "The Diffusion of Iron in Nickel", by M. B. Neiman, A. Ya. Shinyaev and B. G. Dzantiev, *Doklady Akademii Nauk SSSR*, Vol. 91, 1953, p. 265-267.

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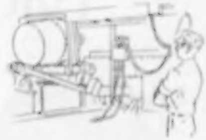

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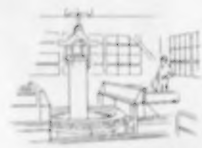

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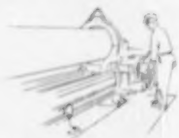

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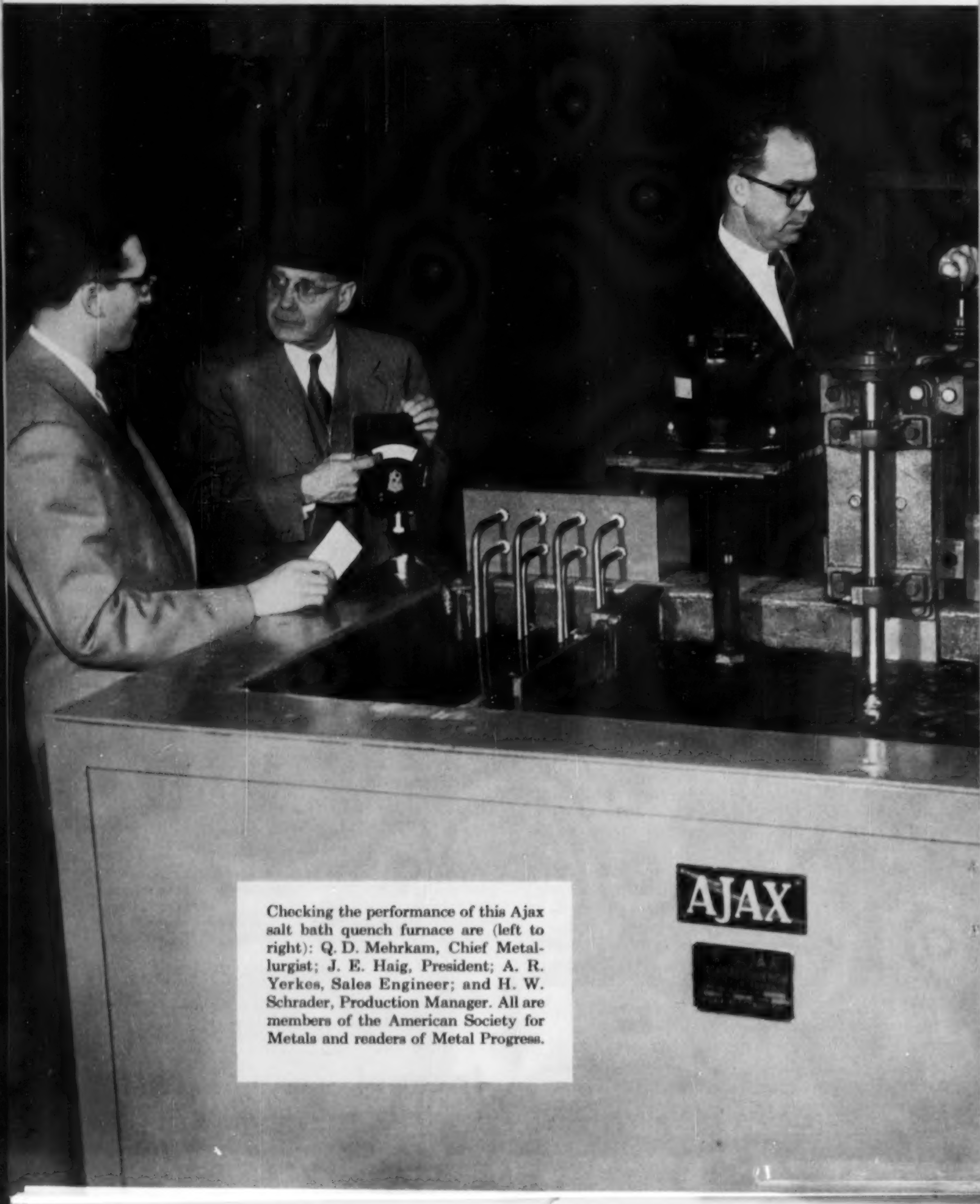


Checking the performance of this Ajax salt bath quench furnace are (left to right): Q. D. Mehrkam, Chief Metallurgist; J. E. Haig, President; A. R. Yerkes, Sales Engineer; and H. W. Schrader, Production Manager. All are members of the American Society for Metals and readers of Metal Progress.


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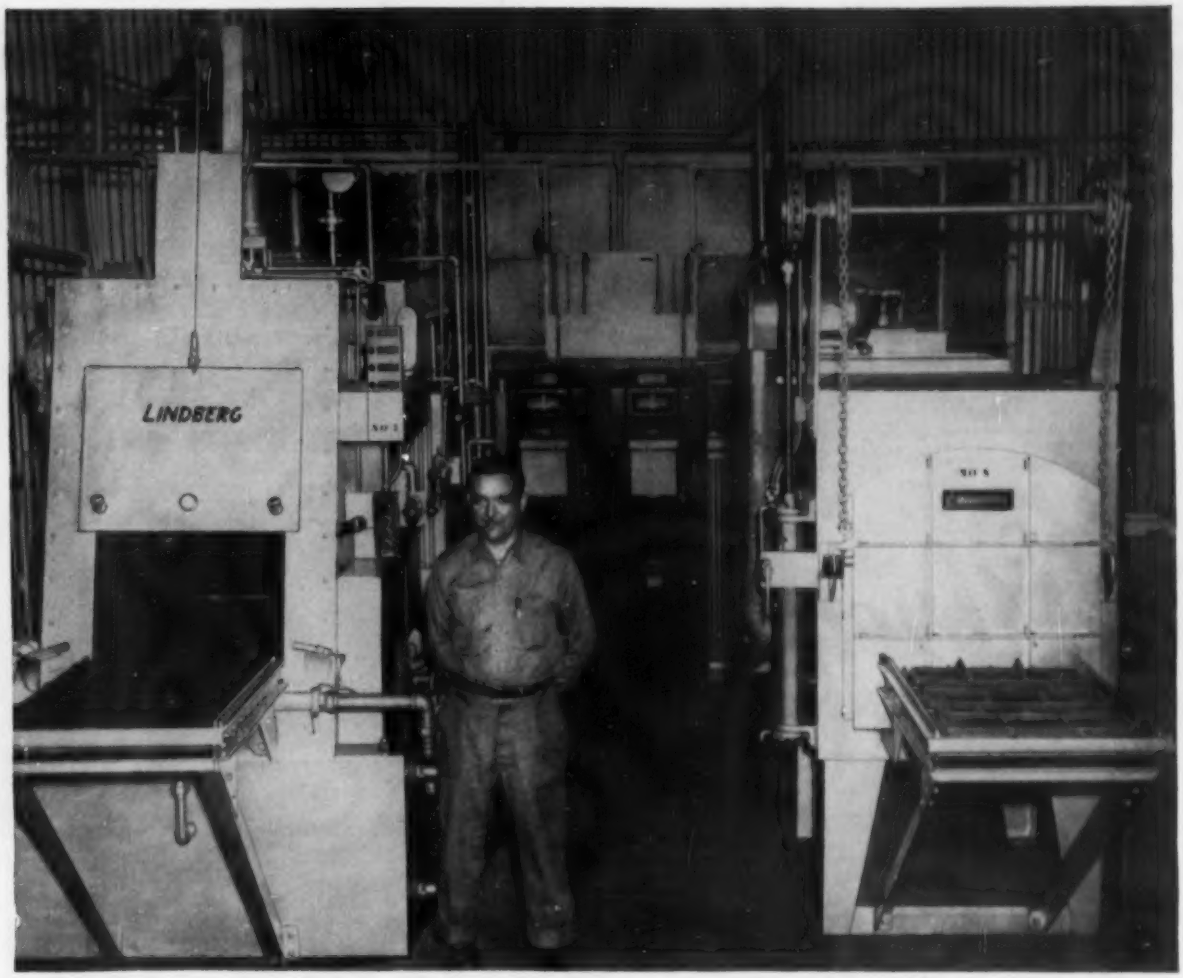
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